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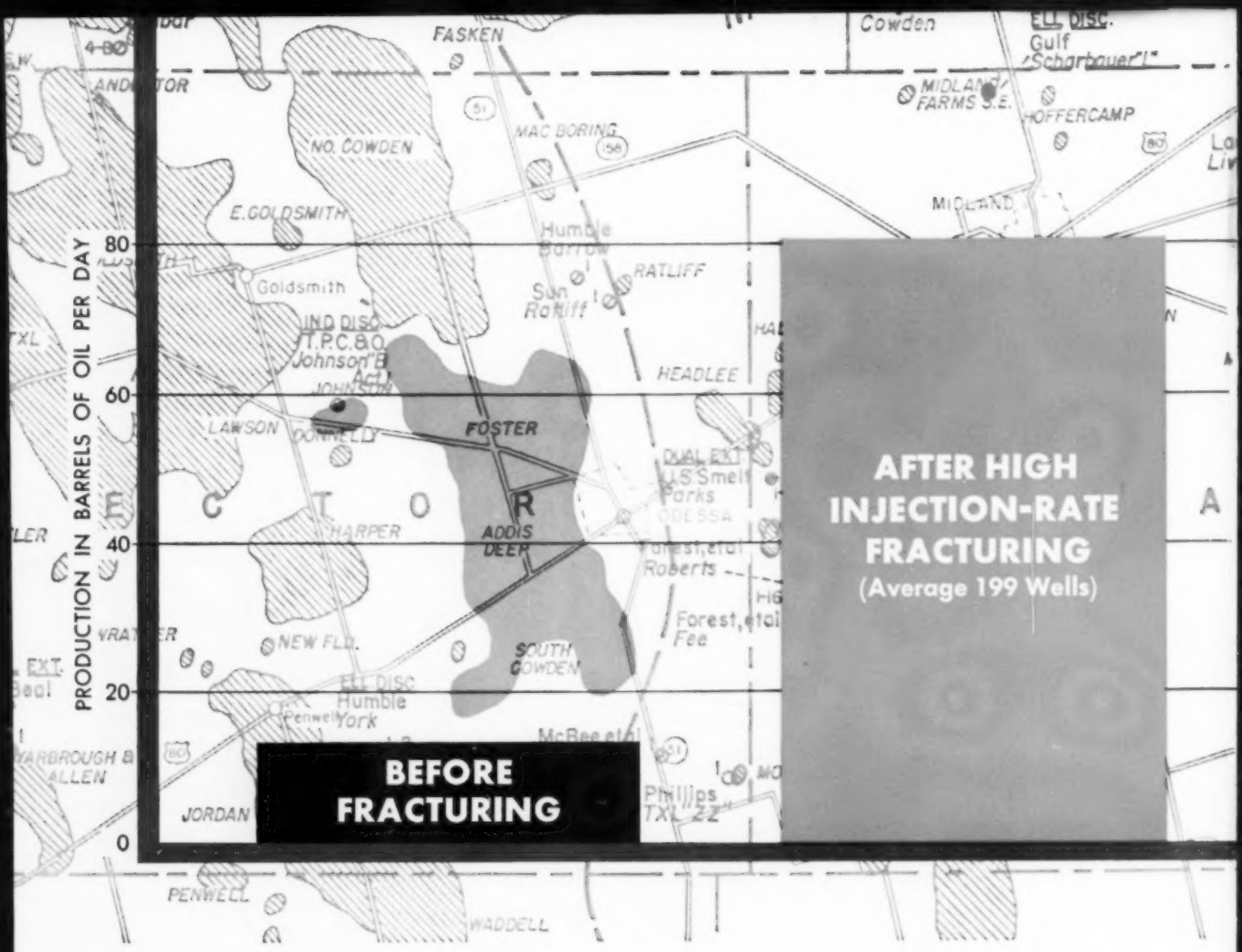

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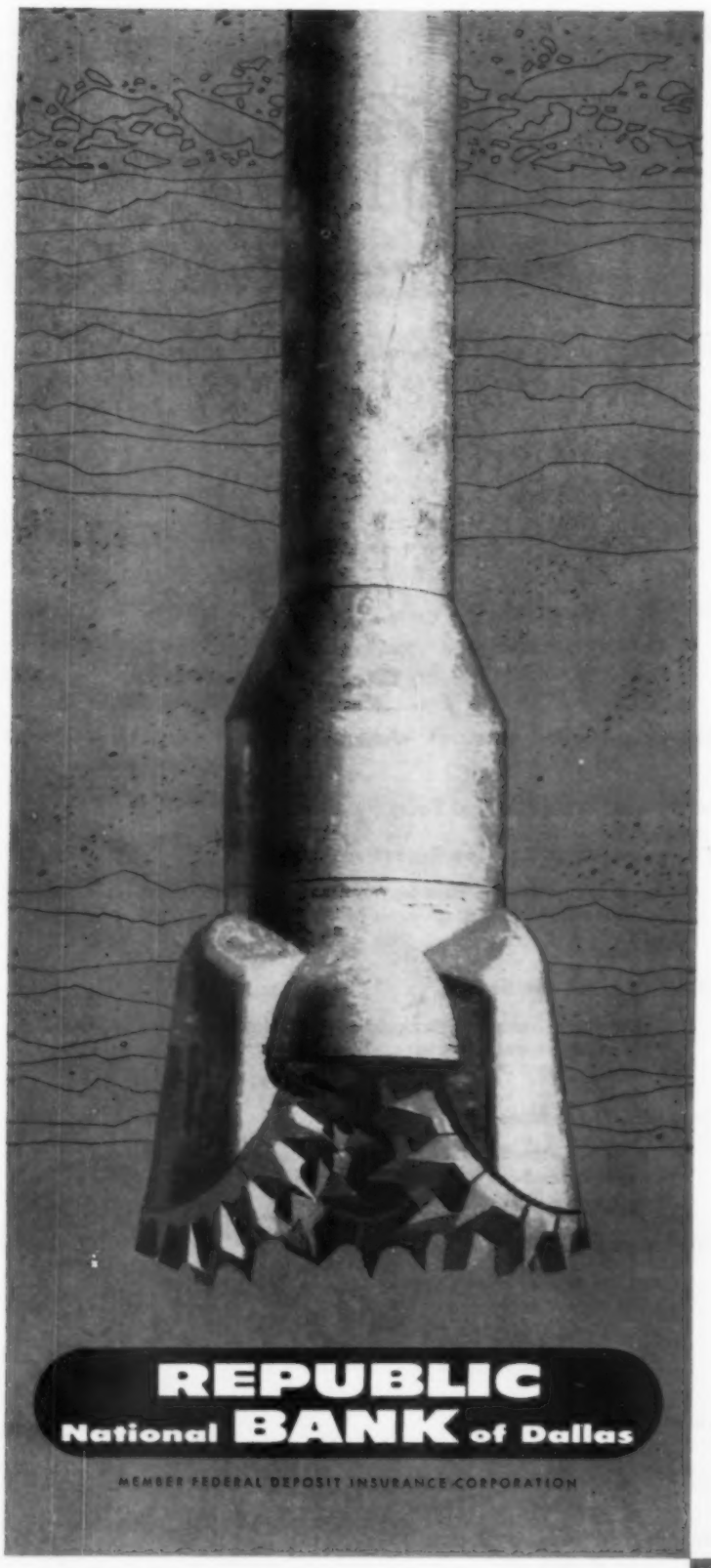

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Automation in some form has been with us many years, only the term itself is of recent origin. Each new step in this machine age has increased the number of jobs — not reduced them.

Automation to each of us has its own definition. Widespread application and rapid development in comparatively recent years have caused many of us to reflect on its effect on our life.

The annual Instrument Automation Conference and Exhibit, sponsored by the Instrument Society of America, which is being held in Cleveland this month, is cause for us to review again what instruments can and cannot do. Also what will be their effect on this industry.

Automation is all around us. Push a button and an elevator comes to pick you up. Push another and it takes you where you want to go. In the field, crude oil can be transferred from field tanks to pipeline automatically under the direction of instruments. Under the supervision of a few men whole refining operations are performed simply and automatically.

The human reaction to new machinery is: "What will this do to my job? Will it put me out of work?" That same question was asked when water pipes were first laid in the cities. And again asked by our forefathers when the tractor, the harvester, radio, power tools, the gasoline engine, etc., came upon the scene.

These, as will automation, proved to be a boon to all lines of endeavor. These inventions have created new jobs, more jobs, made it possible for workers to produce more in less time and for more pay. There is little doubt that automation will result in the same, if not greater, elevation of our standard of living. In fact, the definition of automation might well be: "Machines that lead us to a happier life."

Frank H. Love

Congrats and $25 to J. H. HIGHTOWER, 513 W. Crockett St., Marshall, Texas, for this quip.

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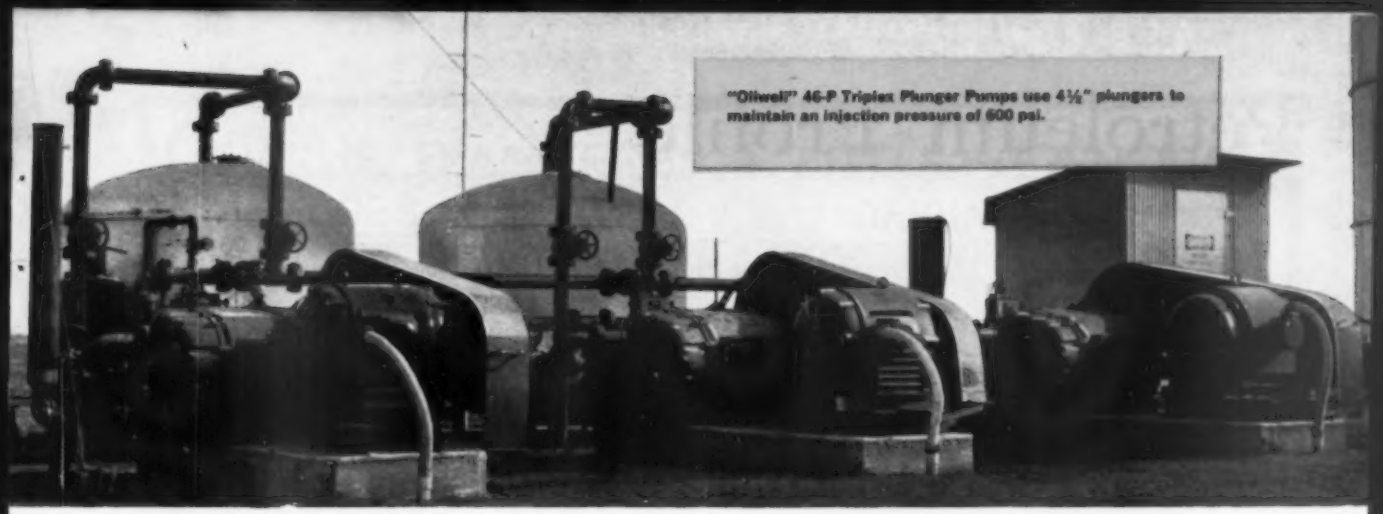

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Petroleum Profile

Arch L. Foster, "dean" of editors, now consulting editor of The Refining Engineer.

THERE is not much doubt about it. Arch L. Foster is one of the real deans of the petroleum industry writers. He has been in the business as a staff writer and editor since 1929 — 28 years! His friends in the petroleum industry and among his fellow editors are innumerable. There are few people, indeed, that haven't heard of this Texas gentleman. All agree that he is a great guy.

Editor of *The Refining Engineer* since August 1948 — then known as The Petroleum Engineer, Refining and Petrochemical Edition – Arch is now shifting to a new and challenging phase of his career, that of consulting and contributing editor for RE. Now he can devote more time to writing and less time to the countless details of editing. Also he will be able to pay more attention to his favorite hobby – guns.

Mr. Foster has been interested in science practically from birth. Raised on a farm near Fort Worth, Texas, he wanted to be a field naturalist. But field naturalists weren't exactly wealthy in the days before 1915, so he decided to tackle chemistry.

This interest had its roots while attending the Grapevine, Texas, high school, where he was curator of the chemical laboratory "at exactly nothing per year." Arch graduated from Southwest Texas Normal School in 1917 after only two years of intensive study; planned to teach science in high schools. But, the U. S. Army had other ideas, and retained his services for a year as a second lieutenant.

When the shooting stopped, Arch went back to school, earning a bachelor's and master's degree in chemistry from the University of Texas. As part of his master's work in 1919-21, he helped Dr. J. R. Bailey, one of the greatest American organic chemists of modern times, in the synthesis of adrenalin.

Gulf Oil Corporation gave Arch his first industrial experience. From 1922 to 1925, he worked for Gulf on aluminum chloride cracking of "solar" oils for gasoline. Then, from 1925 to 1929, he was assistant chief engineer for the Petroleum Division of the Bureau of Mines.

In 1929, he ventured into technical writing. He liked it, spending 10 years with National Petroleum News as technical editor. The way Arch puts it: "I wrote . . . good gravy, how terribly much." Before he joined the Oil and Gas Journal as refining editor in 1942, he had spent two years in the research and patent departments of Phillips Petroleum Company and a year with Lubrizol Corporation as a technical supervisor and editor. Indicative of Arch's imagination is the fact that he has some 20 patents on petroleum processing.

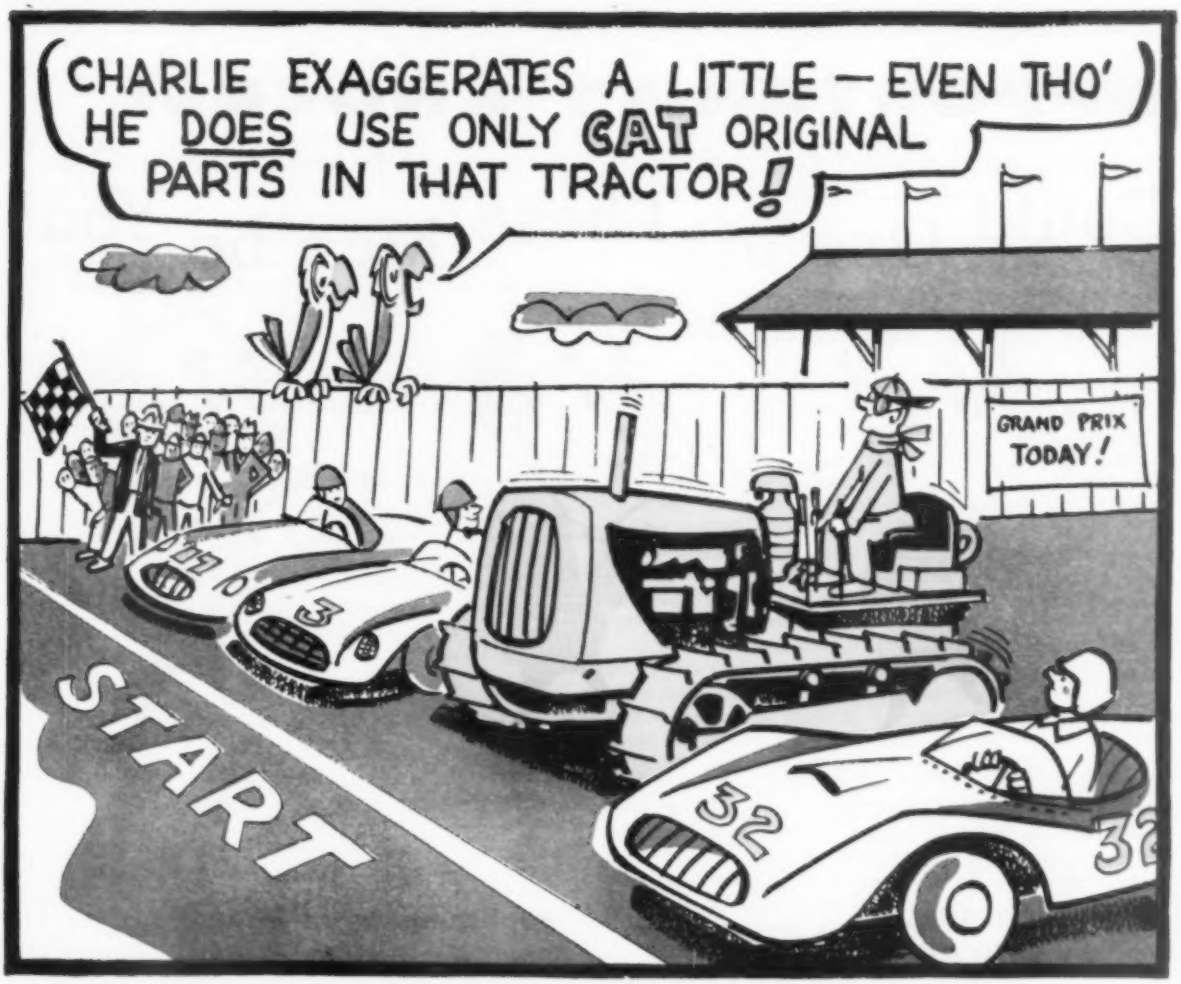
Arch spent his last year with the Oil and Gas Journal in New York. A Texan at heart, he decided to come back to his home "stompins" in August 1948. Ever since, he filled the job of refining, gas processing, and petrochemicals editor for THE PETROLEUM ENGINEER.

Aside from his literary talents, which are legion, Arch holds a number of enviable records as a "gun bug." His collection includes 41 firearms, ranging from classical antiques to the most accurate rifles known. He is president of the Lancaster (Texas) Gun Club, and has fired the smallest bench rest groups in that organization. His other target-shooting achievements leave him with only one more ambition — to fire 10 shots at 200 yards, through a single hole in a paper target "the hole not to be larger than the diameter of the bullets fired."

The annual Western Petroleum Refiners Association meeting in Casper, Wyoming, is Arch's biggest weakness so far as meetings are concerned. It's held in September, at a time coinciding with the pronghorn deer hunting season. Thus, each year that Arch goes to this meeting he breaks a record — that of taking more pronghorns in Wyoming over the years than any one modern man known!

As all readers of petroleum industry business publications know, Mr. Foster's contribution to the industry via the written word are, indeed, many. In presenting current technical events, industry news, and fundamentals, he knows few peers. By his own admission, he has two really big crowning glories . . . that of being the editor of THE REFINING ENGINEER and that of writing seven of nine articles on synthetic rubber that the Oil and Gas Journal published in a special issue of November 26, 1942.

THE PETROLEUM ENGINEER staff is proud to have Arch L. Foster as an associate. His talent and his character as a real Texas gentleman are a big asset. In his new capacity as consulting editor, he will perhaps be able to fulfill his one remaining ambition . . . "to write an article that will please every one of my readers, all advertisers, and the PE management in one fell swoop." His associates believe, along with his thousands of friends everywhere, that he has already done this many times over.



Are they really as much alike as they look? Steel used in industrial standard bolts must withstand 120,000 pounds pull per square inch—CAT* bolts must withstand *at least* 151,000 PSI. Same with other Cat original track parts—higher standards. With "look-alike" track parts, who knows? Be sure to get parts you can trust—from your Caterpillar Dealer. He always has *exactly* the part you need. Call on him anytime.

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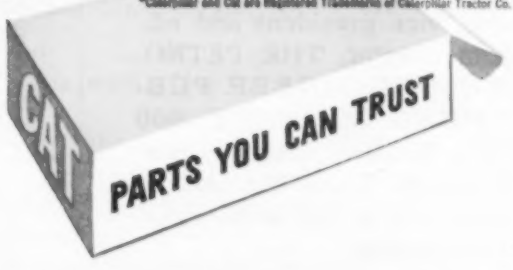

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Graduate engineer, 25 to 30 years old, minimum of two years experience, likes to meet people, has friendly manner, has inquiring mind, a self-starter, likes to write for publication, enthusiastic about his work.

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you want to find out more about these engineering-editor staff positions 'phone or write Frank Love, vice president and editorial director, THE PETROLEUM ENGINEER PUBLISHING COMPANY, 800 Davis Building, Dallas, Texas; Telephone RI 8-4403. *All inquiries will be held in the strictest confidence.*

Publishing is an interesting, worthwhile career

The rapid growth of THE PETROLEUM ENGINEER's specialized editions (THE PETROLEUM ENGINEER — Drilling and Producing, THE PIPELINE ENGINEER, and THE REFINING ENGINEER) makes it necessary to expand our engineering-editorial staff. There are immediate openings for graduate engineers on each of our specialized editions.

The work is highly interesting. As a member of our staff you are an engineer first and an editor-writer second. Writing experience, while desirable, is not necessary. You will attend industry conventions and have the opportunity to make the acquaintance of key people throughout your division of the industry — make occasional field trips, and learn more about the overall scope of our great industry.

Excellent starting salary, traveling expenses, merit increases, and company benefits.

The Petroleum Engineer Publishing Company
Dallas, Texas

THE CONFERENCE TABLE

You Can Find Where It Is

In January of this year Curtis Stevens began publishing the National Petroleum Bibliography, which comes out bimonthly. In book form, each issue runs around 200 pages and presents a working index to all petroleum publications and other publications that deal with petroleum. The venture has been marked with unusual success. There is no advertising and the subscription rate runs $35.00 a year in the United States and Canada. The contents are indexed under the classification system of Professor L. C. Uren, which provides a systematic listing under topic headings for easy reference. Address is Box 3586, Amarillo, Texas.

German Consumption Rising

Home consumption and bunker sales for Western Germany in 1962 will be 30 million tons, market research specialists of oil companies in the country reported to OEEC. This will be more than double actual consumption figure of 1956. About two-thirds of this will fall into the class of fuel oil. Estimates for consumption and bunker sales this year amount to 17.5 million tons. Predictions for next year are for 20 million tons.

Modern Mote

"And so I hold it is not treason
To advance a simple reason
For the sorry lack of progress we decry.
It is this: Instead of working
On himself, each man is shirking
And trying to reform some other guy."

Foundation for Economic Education

Do We Pay for Welfare in Leaders?

When students at Cambridge University and other British institutions were polled about their future, from one-third to more than one-half of the men and women replied that they had already decided to emigrate or were considering it. Almost half who had such plans were scientists.

Reasons given for the lack of interest in pursuing careers in Great Britain was the lack of opportunity; the fact that England was so restricted by regulations, unions and general apathy. The apparent desire of so many of its potential leaders to leave Britain is of grave concern to the people there.

In this country our problem is not so much in keeping the young people at home as it is in persuading them to enter courses that lead to engineering and science. Editorials recently in some of the consumer publications have shown a concern over the apparent indifference of college graduates. They seem to "go along to get along." When the youth of the country expect nothing more than pleasant mediocrity, you have a feeling that the nation has been living on tranquilizers for too long.

And what's the remedy? It's very simple — shift more responsibility back to the individual from the government, and let him keep enough money to do some planning for himself.

Now We're Going to "Peak Out"

The old "We're Running Out of Oil" theme was reiterated recently by Dr. Donald Frey, director of engineering research for the Ford Motor Company, at a University of Michigan lecture. "American production of natural petroleum is likely to 'peak out' within the next 20 years," according to Director Frey, "compelling the country to turn to substitute fuels and to automobiles with greater fuel efficiency."

He predicted that after the petroleum supply peak is reached within 20 years there will be lots of petroleum in the ground but it will be too expensive to pump it out. Then we will turn more and more to foreign supplies and will pay increasingly higher prices. Frey explained "other sources of liquid fuels for automotive systems will become competitive costwise." These include coal, shale, and agricultural products.

One trouble with the oil industry is that you can prove almost anything about it by statistics and then have the industry turn around and prove you wrong. Nearly every prophet we've had so far on oil reserves for the future has had to eat his words.

In this case there are two or three comments that come to mind. One is that in the coming 20 years technological progress may reach vast quantities of new reserves of petroleum and learn how to produce it at economic levels — even at great depths and over deep water.

In figuring higher costs we must also remember that much of this rise is due to inflation. Actually petroleum products have never kept up with the average consumer cost of living increases. If price were figured on a 100-cent dollar and credit given for improved quality the trend would be downward, indicating the huge savings that technological advance has given us. Taxes alone have gone up enough to offset most other gains from efficiency.

Motors Pass 100 Million

Motor vehicles in the world today are almost 103 million. Excluding Communist countries, the total is 99 million.

This is 8 percent more than last year. Western Europe made particularly sharp gains, jumping 18 percent.

Highway building will be pushed all over the world to handle greater and greater road traffic. OEEC predicted motor vehicles would increase to about 25 million in 1960. It looks as if this figure is too low.

World Motor Census, 1956 and 1957.
(Thousand Units; beginning of year)

	(Revised) 1956	1957
United States	62,040	64,601
Canada	3,831	4,323
Other Western Hemisphere	2,979	3,335
Western Europe[1]	16,284	19,316
USSR	2,875	3,130
Other eastern Europe	567	588
Oceania	2,734	2,950
Asia	2,268	2,594
Africa	1,888	1,991
Total World	95,466	102,828[2]
Of which:		
Cars	73,117	78,815
Lorries and buses	22,304	23,961
Unspecified vehicles	45	52

[1]OEEC countries, also Spain, Finland and Yugoslavia.
[2]Total, excluding Iron Curtain Countries, 98,972,000.
Source: The American Automobile, May 1957.

HIGHLIGHTS

★ ★ ★

Digest of News and Comment

Voluntary oil imports cutback plan, announced early in August by President Eisenhower, continues to be met with mixed comment. It is being hailed as a "striking victory" for the U. S. oil industry by domestic oil men and denounced by the National Oil Jobbers Council as doing "irreparable damage" to international relations. AAODC officials say it will help the drilling industry. "It won't work," say some association heads; "It won't make much difference," says Texas RR Commissioner Olin Culberson. "It's a pure washout," says Anderson-Prichard Oil President Roland Rodman, and TIPRO states it only "recognizes the problem."

★ ★ ★

Price cuts on Pennsylvania grade crude oil, posted recently by the Joseph Seep Purchasing Agency, were necessary to "balance future production with refiners' demand," the buyers contend. The 23 cents-per-barrel cut is a reversal of a long trend of increases beginning in September 1954. Since that date the price of Bradford District crude had risen from $3.23 to $4.88. New price is $4.65.

★ ★ ★

Legislation to open new Iranian concessions to foreign oil companies has been cleared. New law will permit companies to negotiate with National Iranian Oil Company for oil exploration and development rights either as independents or on a 50-50 profit-sharing basis with the government. It has been suggested that Enit-Agip, the Italian government oil company, will be the first to take advantage of the new plan. Negotiations are already underway by American, Japanese and German companies for exploration rights in the Qum and Baluchistan areas.

★ ★ ★

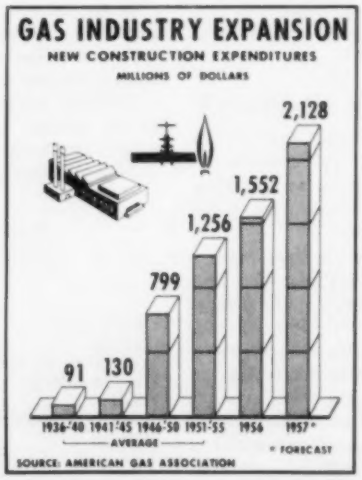
Free world oil records were set in several realms of activity, reports Frederick Coqueron in his annual analysis of the oil industry for the Chase Manhattan Bank. Crude reserves at the end of 1956 were 200 billion barrels—highest level in history. Some 70 percent of these reserves are in the Middle East, 15 percent in the U. S., 7 percent in Venezuela and the remaining 8 percent in other free nations. Crude oil production set a new daily average high of 14,800,000 bbl — up 7.9 percent above 1955. New levels in earnings were attained by American oil companies, with the 33 major companies reporting a total net income of $3 billion — a 12.6 percent increase over the previous year.

★ ★ ★

Biggest western Canada Oil and gas company merger is being completed by Pacific Petroleums, Ltd., and Merrill Petroleums, Ltd. The estimated $200,000,000 amalgamation is being made on the basis of one share of Pacific for two shares of Merrill. Reason cited for the merger was to give Merrill stockholders a more diversified investment and increase growth potential. The acquisition substantially increases Pacific's status among independent integrated Canadian companies.

★ ★ ★

Demand for oil tankers has boosted world shipbuilding to an all-time peacetime record in the second quarter of 1957, reports Lloyd's Register of Shipping. On June 30 a total of 8,778,635 gross tons of shipping was under construction — an increase of more than 396,000 tons over the first quarter. Tankers accounted for 337,000 tons of the increase, amounting to almost half of the total tonnage under construction. There are 294 tankers now being built, according to Lloyd's.



The gas utility and pipeline industry is expanding this year at the fastest pace in its history with construction expenditures of more than two billion dollars. This is 37 percent higher than last year and more than triple the annual average for the previous 20 years. The industry is adding about a million customers a year and currently serves more than 30 million customers through utility gas lines.

Meeting of the National Petroleum Council has been called by Chairman Walter S. Hallanan on October 3 in Washington, D. C. An all-out attendance is being urged in view of the importance of committee reports to be made and other problems concerning petroleum on which the Secretary of the Interior and the Director of Oil and Gas may request advice.

★ ★ ★

Pipeline to parallel the Suez Canal is expected to begin construction soon with financing by the Egyptian government and a foreign combine. The proposed 26 to 32-in. line is expected to cost $36,400,000 and will have a 500,000 bbl per day capacity. Completion is due about 12 months from the starting date.

★ ★ ★

Five more tankers have been ordered by Socony Mobil Oil Company at a total cost of $45,000,000. The new contract, made with a Swedish firm, raises to 16 the number of new tankers now being built or on order for Socony Mobil companies, representing a total investment of $140,000,000. The new contract calls for construction of five 48,600 ton supertankers to be delivered between 1960 and 1963.

★ ★ ★

A special grant of $1,500,000 to finance a three year program for stimulating education in science and engineering has been made by Jersey Standard. Esso Education Foundation will distribute the funds to educators of secondary schools and to colleges and universities. The grant, marking the seventy-fifth anniversary of the company, will be in addition to substantial grants to be made by the Foundation later this year.

★ ★ ★

Pemex will get French financing for its expanding drilling, exploration and exploitation program. Five French banks are offering the Mexican-government owned oil company $50,000,000 for equipment purchases. This is the first time that the company has gone outside the Mexican border to obtain capital for its operation. Under preliminary terms, Pemex will have a free hand in selecting equipment from French firms, but purchases must be approved by the banks. It is understood that this is but the first phase in the program and will be extended to include financing for much needed refining equipment.

SCRUBOSPHERE* ...

... FOR *Cleaner Gas* AT *Less Cost!*

*PEERLESS SPHERICAL
DUST and LIQUID SCRUBBER
FOR GAS PIPELINES

(A) The majority of incoming liquid and solid particles are directed down into reservoir. 1

(B) Lighter solid particles carried by gas stream are separated on surfaces of contactor which are kept wet and clean by revolving them through liquid reservoir. 2

(C) Contactor is revolved by explosion-proof gear motor.

(D) Mist Extractor removes any remaining liquid particles from gas stream prior to outlet. 3

- The **dust removal ability** of the SCRUBOSPHERE **is superior** because it utilizes wetted surfaces for dust collection which are much more closely spaced than in conventional equipment.
- **Oil loss is minimized** because the oil used to wet the dust collecting surface is lifted mechanically instead of bubbling gas through the oil which results in foaming and loss due to creation of hard-to-separate fine particles.
- **Maximum performance and low cost** — The spherical design means high capacity and performance because it provides maximum dimensions for the contactor and mist extractor which normally are limiting factors in scrubber designs. The vessel cost is reduced because required vessel thickness is only one half that required for cylindrical vessel of same diameter.
- **Versatility** — separates solid and liquid particles with equal efficiency.
- **Low pressure drop** — ½ to ¾ psi at rated capacity depending on nozzle size.

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PEERLESS MANUFACTURING CO.

P. O. BOX 13165 DALLAS, TEXAS

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Write for test data showing dust removal and oil loss of Peerless Scrubosphere as against conventional dust scrubber.

Increasing export business of the oil and gas industry equipment manufacturers, supply and service companies will boost foreign attendance to the International Petroleum Exposition, May 14-23, 1959. The Tulsa, Oklahoma, show has attracted oilmen from over 50 countries in the past, say General Manager William B. Way and W. K. Warren, chairman of the board of Warren Petroleum Corporation and exposition president (shown here). The Nomads organization will serve as hosts to delegates attending from other countries.

★ ★ ★

Several Kansas counties recently filed suits against the state's new oil and gas severance tax. County attornies of Barton, Greenwood, McPherson, Stevens, and Wilson counties, and officials of Associated Industries, Inc., filed the suits in Kansas Supreme Courts. They claim the new tax act attempts to classify royalty owners as producers; that uniform and equal provisions of the constitution are not complied with; the act results in impairing the obligation of contracts, and that certain classifications of the act are special and void.

★ ★ ★

A reduction in military oil purchases in the new fiscal year has been ordered by the Navy, which purchases petroleum products for all armed services. The cutback will trim from 10 to 15 percent of purchases from the scheduled $1,143,000,000 to be spent during the 12 months ending next June 30. Although the decrease will affect all services, the greatest impact will be felt in demand for the Navy's special fuel oil and all aviation fuels.

★ ★ ★

Jerome K. Kuykendall received Senate approval for reappointment to the Federal Power Commission by a vote of 50 to 25. President Eisenhower's reappointment of Kuykendall had met with sharp attacks from some western senators who accused him of favoring private utilities and natural gas producers at the expense of consumers. Defending senators said that his opponents were disgruntled because of unsuccessful fights for projects such as Hell's Canyon Dam.

★ ★ ★

Charges of "basic instability in the entire petroleum industry" have been hurled by a House Small Business subcommittee, headed by Rep. Roosevelt of California. The group plans to study oil supply and demand problems next year that stem from complaints that have "symptoms of more basic causes that possibly arise from a current over-abundance of oil." In the past the subcommittee had confined its investigations to hearings on practices of distributors, jobbers, and retailers of oil and allied products.

★ ★ ★

A service station for the "discriminating" who want to know more about gasolines, lubricants, and new automobiles has been opened in Dallas, Texas, by Magnolia Petroleum Company. Purpose of the new station-laboratory is to answer questions of both motorists and service station personnel, and to pass on the results of point-of-purchase research to the company's marketing area.

★ ★ ★

Objections to the voluntary oil imports control will be heard by the program's director, Capt. M. V. Carson at a meeting tentatively scheduled this month. Seven of the 22 importers have protested the import quotas assigned to them. In spite of the objections, Carson maintains the new plan will receive almost complete cooperation. Of the eight companies protesting, only Sun Oil Company said it "did not believe it could comply."

★ ★ ★

Oil and the oil search has netted the state of North Dakota $12,129,-434.44 in direct receipts. The total includes bonuses, rentals and royalties, and oil and gas production taxes. Leases and bonuses on state lands amounted to $4,995,874.

★ ★ ★

New office building for the British Petroleum Company is now under construction at a bombed-out site near London. The new structure, called the BP House, is going up only a few hundred yards from the company's headquarters, the Britannic House. New building is H-shaped, comprising two seven-story wings and a 12-story center block.

★ ★ ★

Colorado Oil and Gas Corporation is continuing its fast-moving integration program. Latest move is marked by the acquisition of Deem Oil Company, East St. Louis, Illinois, and its affiliated companies. Newest transaction will strengthen refining and marketing operations of Derby Refining Company, a wholly-owned subsidiary of Colorado Oil and Gas, and will open new markets in Illinois and Missouri.

Whit Downer Named Editor, Arch L. Foster Consulting Editor of The Refining Engineer

S. W. (Whit) Downer III, who has been associate editor, has been named editor of *The Refining Engineer*, a specialized edition of *The Petroleum Engineer*, for engineering-operating personnel in the petroleum refining, gas processing, and petrochemicals industries.

In his new post, Mr. Downer will be responsible for article content, features, and other editorial aspects of the publication. Prior to joining The Petroleum Engineer Publishing Company he was a process engineer with Esso Standard Oil Company's technical service division, in Linden, New Jersey. He is a graduate chemical engineer, and has done extensive graduate work in the field of business administration.

He has written many key articles for *The Refining Engineer*, including a 14-page report on Tidewater Oil Company's new refinery on the East Coast and an extensive report on instrumentation and control that appears in this month's issue of *The Refining Engineer*.

Arch L. Foster, subject of this month's Petroleum Profile (page A-8), who has been editor of RE since 1948, is assuming a semi-retirement status. His services will not be lost to the oil industry, however. He will continue as a consulting editor, and will contribute special feature articles from time-to-time.

Good Wells Make Good News

September 1957

SUCCESSFUL ACID TREATMENTS depend largely on the way they are "tailored" to the requirements of the well. Here are four examples of excellent results obtained from Dowell-tailored acid treatments.

- **Wabash County, Illinois** (New Well): Open hole completion in highly soluble O'Hara lime, 2876 to 2884 feet, tested 12 bopd. Since regular acid had given poor results in nearby wells, Dowell recommended Acid Petrofrac®. A 3000-gallon treatment was performed, down 4½-inch casing preceded by a 500-gallon spearhead of mud remover acid. *After treatment, well stabilized at 75 bopd and treatment paid out in less than ten days!*

- **Webster Parish, Louisiana** (New Well): First attempt to acidize this Smackover lime interval, 11,268 to 11,297 feet, unsuccessful because cold acid shrunk the tubing and allowed communication through the packer. Dowell suggested heated acid, prepared by mixing 60 barrels 28% acid with equal quantity hot water—heated to 150°F. by paraffin solvent heater. Well acidized successfully without communication despite 5000 psi tubing pressure. Results: *Well tested 126 barrels 57 gravity oil in 11 hours through 12/64-inch choke.*

- **Washakie County, Wyoming** (Old Well): Production from highly soluble Embar lime had declined to 10 bopd. Sour crude indicated presence of iron sulfide. Since regular acid dissolves iron sulfide and might let it reprecipitate as iron hydroxide, Dowell suggested Stabilized Acid. 30 days after treatment with 3000 gallons, *production was steady at 100 bopd.*

- **San Juan County, Utah** (New Well): Well first perforated and completed in Upper Paradox lime of Aneth Pool, 5628 to 5648 feet. Well was given Retarded Acid treatment with Mud Acid spearhead. Following a 71 boph test, well was killed with mud and the Lower Paradox tested. After lower zone proved non-productive upper zone would not respond to normal mud removal techniques. To remove mud, 10,000 gallons Retarded Acid was used. After first 6000 gallons down annulus at 7½ bpm, 100 ball sealers were used. *Well swabbed 70 boph, indicating successful treatment.*

Regardless of your problem, you can depend on Dowell's fund of knowledge, addition agents and experience to "tailor" acid treatments to your needs. For service or more information, call any of the 165 Dowell offices in the United States and Canada; in Venezuela, contact United Oilwell Service. Or write Dowell Incorporated, Tulsa 1, Oklahoma.

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Speeds oil field maintenance • construction • material-handling

Consider what the high-speed mobility and *extra capacity* of this Koehring 205 truck crane can mean on your scattered lifting and material handling work around refineries, yards, booster stations, drill sites, etc. It travels anywhere a truck will go — drives 30, 40 miles, or more, in less than an hour's time.

Unrestricted travel

Axle-load distribution of the 205 truck crane conforms with street and highway regulations in most areas, even when carrying 25-foot boom over the steering end. Overall width is 8 feet.

With one of these mobile cranes on hand, you're equipped to lift any load up to 15 tons (based on conservative 85% rating). For high lifts, the pin- or butt-connected crane boom can be extended from 25 to 70 feet. When extra reach is needed, 15 or 30-foot jib can be added to 65-foot boom, for a maximum 95-foot boom-and-jib.

½ to ¾-yard bucket

Heavy lifting capacity and stability of truck mounting increase the 205's work capacity with every attachment. It handles ½ to ¾-yard clamshell bucket on a wide work radius — speeds stockpiling, loading and unloading of coal, chemicals, and other bulk materials.

When there's excavation to be done for new installations, foundation footings, truck-road maintenance, drainage, plant pipeline systems, the Koehring 205 readily converts to dragline, ½-yard shovel or hoe — earns extra savings for you. It's also profitable for "spare-time" rental service to local contractors, cities, and neighboring industries if you like!

Take your choice:

To suit your working conditions, this Koehring 205 is available on a choice of truck, Cruiser®, or crawler mountings. Better see your Koehring distributor about it soon — or write us for more information. Other Koehring sizes up to 95 tons or 3 yards also available.

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Meetings

Sept. 3-5—**Pacific Coast Gas Association Convention,** San Francisco, California.

Sept. 5-6—**API Oil Information Committee meeting,** Broadmoor Hotel, Colorado Springs, Colorado.

Sept. 8-13—**American Chemical Society,** 132nd national meeting, New York City.

Sept. 9-11—**American Institute of Electrical Engineers,** petroleum industry conference, Sheraton Hotel, Philadelphia, Pennsylvania.

Sept. 9-13—**12th Annual Instrument Automation Conference and Exhibit,** sponsored by Instrument Society of America, Cleveland Auditorium, Cleveland, Ohio.

Sept. 10-11—**Petroleum Packaging Committee,** quarterly meeting, Hotel Guildwood Inn, Point Edward, Ontario, Canada.

Sept. 11-13—**National Petroleum Association,** 55th annual meeting, Hotel Traymore, Atlantic City, New Jersey.

Sept. 12-14—**Wyoming Geological Association,** 12th annual field conference, Southwestern Wind River Basin, Lander, Wyoming.

Sept. 15-18—**AIChE,** Lord Baltimore Hotel, Baltimore, Maryland.

Sept. 22-24—**Independent Oil Compounders Association,** 10th annual meeting, Carter Hotel, Cleveland, Ohio.

Sept. 22-25—**American Society of Mechanical Engineers,** Petroleum Division, 12th annual Petroleum Mechanical Conference, Mayo Hotel, Tulsa, Oklahoma.

Sept. 23-24—**Steel Founders' Society of America,** 55th fall meeting, The Homestead, Hot Springs, Virginia.

Sept. 23-25—**American Society of Mechanical Engineers,** fall meeting, Statler Hotel, Hartford, Connecticut.

Sept. 25—**Natural Gasoline Association of America,** regional meeting, Northern Hotel, Billings, Montana.

Sept. 26-27—**Western Petroleum Refiners Association,** regional technical-industrial relations meeting, Henning Hotel, Casper, Wyoming.

Sept. 26-27—**Louisiana-Arkansas Division Mid-Continent Oil & Gas Association,** annual membership meeting, Roosevelt Hotel, New Orleans, Louisiana.

Sept. 30-Oct. 2—**American Oil Chemists' Society,** 1957 fall meeting, Netherland Plaza Hotel, Cincinnati, Ohio.

Oct. 1-2—**Texas Mid-Continent Oil & Gas Association,** 38th annual meeting, Texas Hotel, Fort Worth, Texas.

Oct. 1-2—**API Executive Committee of Board of Directors,** Greenbrier Hotel, White Sulphur Springs, West Virginia.

Oct. 6-9—**The Society of Petroleum Engineers, AIME,** annual fall meeting, Adolphus, Baker and Statler-Hilton hotels, Dallas, Texas.

Oct. 6-10—**ASTM Committee D-2 meeting,** Sheraton-Park Hotel, Washington.

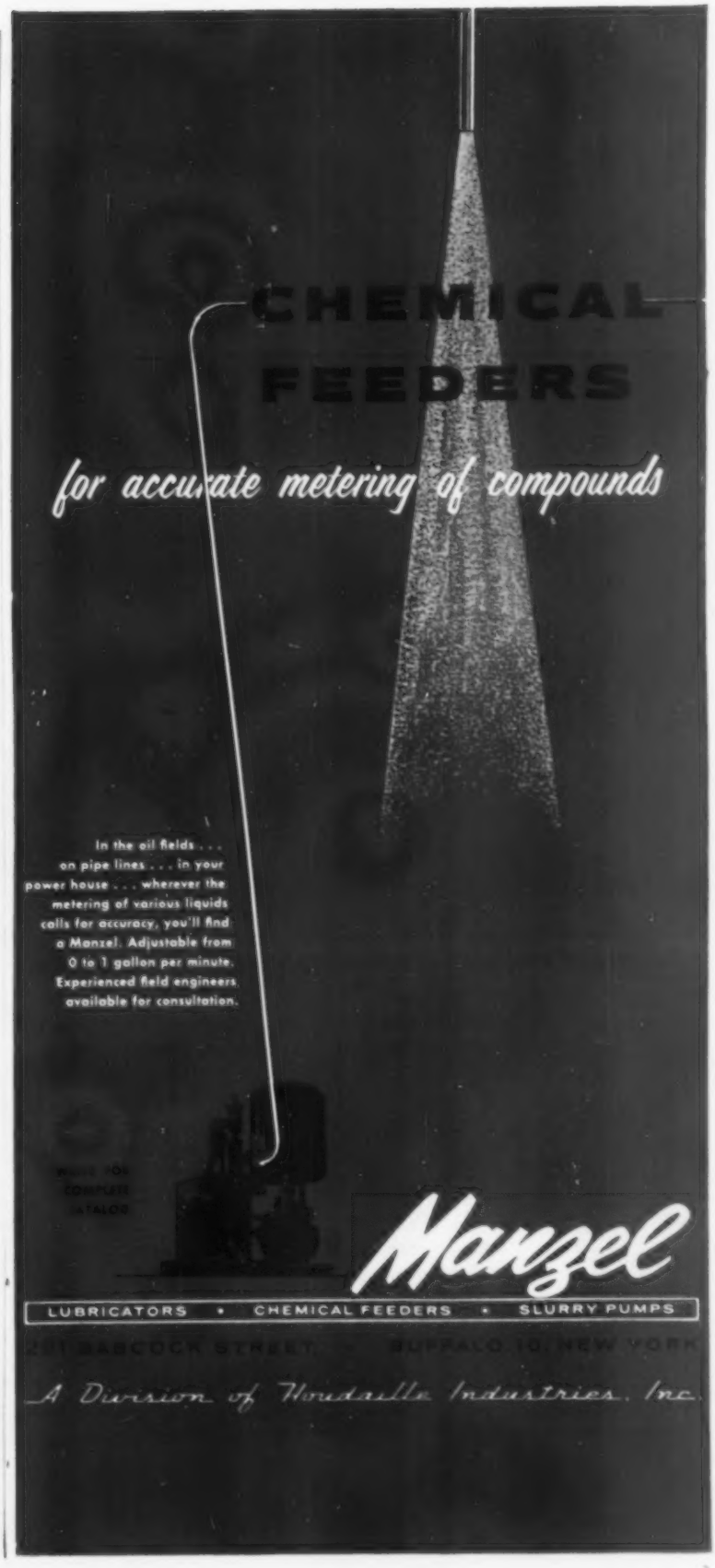
Oct. 7-9—**ASME, ASLE-ASME Lubrication Conference,** Royal York Hotel, Toronto, Ontario, Canada.

Oct. 7-9—**American Gas Association,** annual convention, Kiel Auditorium, St. Louis, Missouri.

Oct. 7-9—**National Electronics Conference,** 13th annual, co-sponsored by Illinois Institute of Technology and two other universities and two technical societies, Hotel Sherman, Chicago, Illinois.

Oct. 7-11—**American Institute of Electrical Engineers,** 1957 fall general meeting, Morrison Hotel, Chicago, Illinois.

Oct. 10-11—**California Natural Gasoline Association,** 32nd annual fall meeting, Huntington-Sheraton Hotel, Pasadena, California.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In the oil fields . . . on pipe lines . . . in your power house . . . wherever the metering of various liquids calls for accuracy, you'll find a Manzel. Adjustable from 0 to 1 gallon per minute. Experienced field engineers available for consultation.
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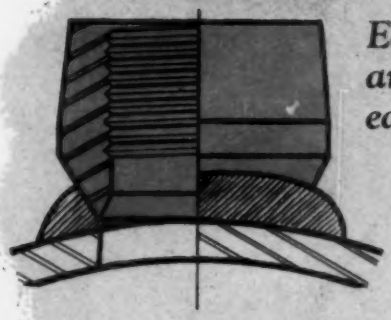
A New Line of Branch Connections

W-S COUPLETS



Economical and easy-to-install

Readily modified for small diameter installation

W-S Couplets are designed to function as universal outlet connections for tanks, process vessels and pipelines. They eliminate the need for large, expensive field inventories and costly delays in fabrication.

On most tank, and large piping installations they are used as received. On those few applications where attachment is to be made to a small diameter pipe, the W-S Couplet is easily modified by contouring the welding end with an acetylene torch to mate with the curvature of the pipe diameter. Couplets are made with extra length and heavy wall to permit contouring without detriment to the threaded or socket end.

W-S Couplets are available in sizes ¼" through 2", with screw-end or socket-welding dimensions ... also in a 90° elbow.

Send for Bulletin CP-1-57. Write to W-S Fittings Division, H. K. Porter Company, Inc., P. O. Box 95, Roselle, N. J.

H. K. PORTER COMPANY, INC.
W-S FITTINGS DIVISION

Oct. 10-12—**ASME, Fuels-AIME conference,** Chateau Frontenac, Quebec City, Quebec, Canada.

Oct. 10-13—**Louisiana Gulf Coast Oil Exposition,** Lafayette, Louisiana.

Oct. 13-15—**American Association of Oilwell Drilling Contractors,** 17th annual meeting, Mayo Hotel, Tulsa, Oklahoma.

Oct. 13-16—**American Petroleum Credit Association,** 33rd annual conference, Mark Hopkins Hotel, San Francisco, California.

Oct. 15-16—**Gas Measurement Institute,** 5th annual, American Legion Hall, Liberal, Kansas.

Oct. 16-17—**South Dakota Independent Oil Men's Association convention,** Alonzo Ward Hotel, Aberdeen, South Dakota.

Oct. 17-18—**The Society of Petroleum Engineers, AIME,** Southern California Petroleum Section, fall meeting, Biltmore Hotel, Los Angeles, California.

Oct. 17-19—**National Society of Professional Engineers,** fall meeting, Grand Pacific Hotel, Bismarck, North Dakota.

Oct. 18—**American Institute of Chemical Engineers,** 12th annual technical meeting of the South Texas section, Moody Convention Center, Galveston, Texas.

Oct. 20-22—**National Association of Oil Equipment Jobbers,** annual convention and trade show, Hotel Peabody, Memphis, Tennessee.

Oct. 21-23—**American Society of Mechanical Engineers,** conference on development in the field of power, Allentown, Pennsylvania.

Oct. 23-24—**Computer Applications Symposium,** sponsored by Armour Research Foundation, Hotel Sherman, Chicago, Illinois.

Oct. 24-25—**Western Petroleum Refiners Association,** regional technical-industrial relations meeting, Rufus Garrett Hotel, El Dorado, Arkansas.

Oct. 25—**Natural Gasoline Association of America,** southern regional, Washington-Youree and Captain Shreve hotels, Shreveport, Louisiana.

Oct. 27-29—**Independent Petroleum Association of America,** annual meeting, Statler-Hilton Hotel, Dallas, Texas.

Oct. 28-31—**American Nuclear Society,** 2nd winter meeting, Henry Hudson Hotel, New York City.

Oct. 31-Nov. 1—**AAPG, Mid-Continent** regional meeting, Mayo Hotel, Tulsa, Oklahoma.

Nov. 6-8—**Gulf Coast Association of Geological Societies,** 7th annual convention, Roosevelt Hotel, New Orleans, Louisiana.

Nov. 10-14—**Society of Exploration Geophysicists,** national convention, Statler-Hilton Hotel, Dallas, Texas.

Nov. 11—**API, OIC,** Steering Committee meeting, Conrad Hilton Hotel, Chicago, Illinois.

Nov. 11-13—**Steel Founders' Society of America,** 12th Technical and Operating Conference, Carter Hotel, Cleveland, Ohio.

Nov. 11-14—**API,** 37th annual meeting, Conrad Hilton Hotel and Palmer House, Chicago, Illinois.

Nov. 12-13—**API Board of Directors** meeting, Conrad Hilton Hotel, Chicago, Illinois.

Nov. 12-14—**National Association of Corrosion Engineers,** Northeast region, fall meeting, Penn-Sheraton Hotel, Pittsburgh, Pennsylvania.

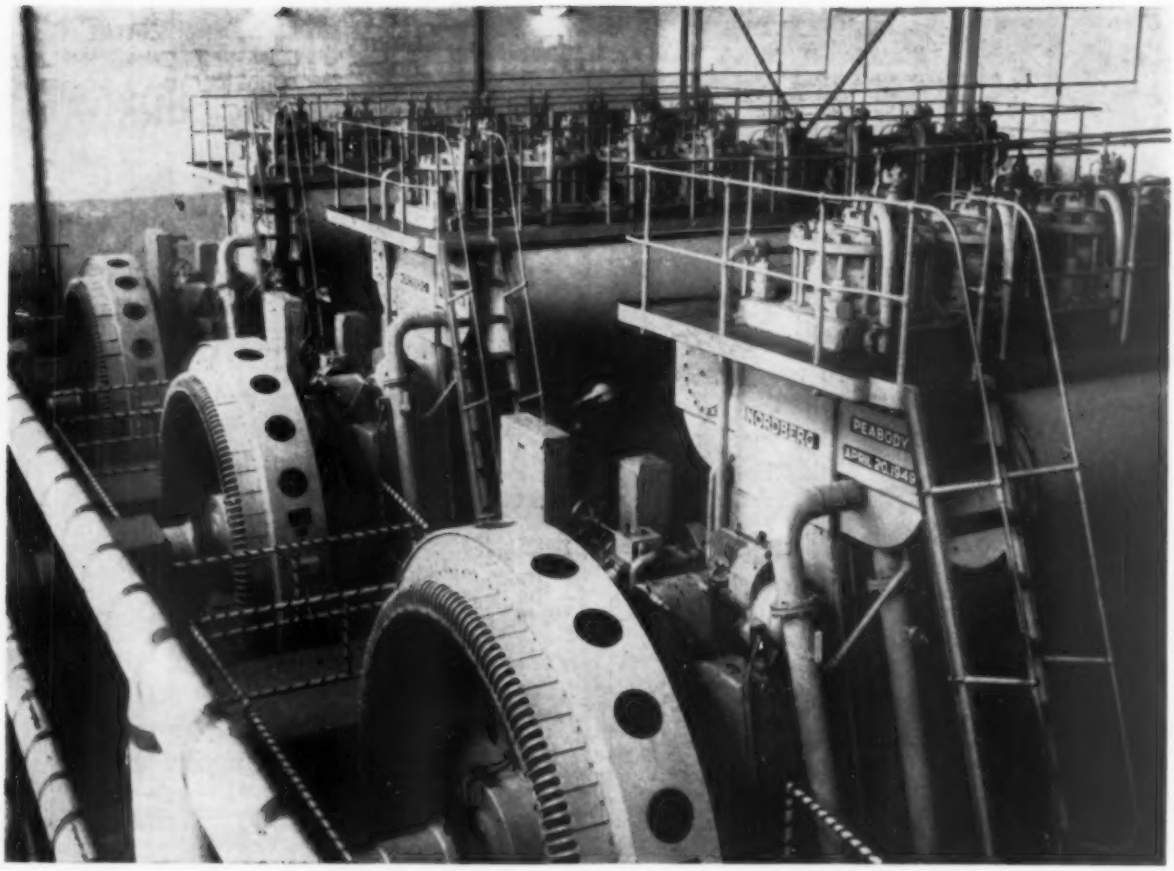
Nov. 13-14—**Air Pollution Conference,** co-sponsored by Armour Research Foundation and Midwestern Air Pollution Prevention Association, Loop Hotel, Chicago, Illinois.

Nov. 22—**Natural Gasoline Association of America,** Panhandle Plains regional, Herring Hotel, Amarillo, Texas.

Dec. 1-6—**American Society of Mechanical Engineers,** annual meeting, Statler Hotel, New York City.

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS SEE READER SERVICE CARD

Look to **COOK** for Better Rings!

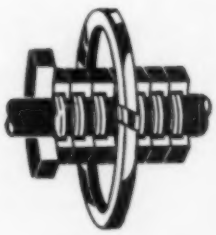


Peabody, Mass. Electric Company Swears by Cook Piston Rings!

Better Performance Since Installation of Cook Rings!

All three of Peabody Electric Company's 3200 H.P. Diesel engines are shown here. In 1956 these engines were required to operate 11,375 hours and generated 19,609,100 kilowatt hours. All three were equipped with Cook Piston Rings and gave trouble-free performance throughout the year.

This record is a tribute to Peabody's excellent management and operating personnel — *and* to the outstanding quality of Cook Piston Rings. If you're looking for a seal with the savings built in, write direct for product information and the name of your nearest representative. Address: C. Lee Cook Company, 948 South 8th Street, Louisville 3, Kentucky.



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IMPROVED SHELL LPI PROCESS FOR BUTANE ISOMERIZATION IS 5 WAYS BETTER

Shell's Liquid Phase Isomerization
makes it more economical than ever to
convert n-butane to isobutane

NEW PROCESS SCHEME MEANS:

1. highest conversion of any known process
2. lower process plant cost
3. high flexibility—with minor addition can isomerize n-pentane
4. high stream factor
5. lower cost of isomerizate fractionation

For technical details and cost estimate, see your engineering contractor. LPI process is licensed by Shell Development Company, 50 West 50th Street, New York 20, New York.

SHELL DEVELOPMENT COMPANY

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THE HAMMOND DIALIFT

the only membrane type conservation tank

... with full-rated vapor and product capacity at all times

... with a membrane that cannot come in contact with product

... with vapor space that can be isolated for inspection and maintenance without taking tank out of service.

Principle of the Hammond Dialift

A—DIALIFT DIAPHRAGM rises and falls to accommodate expanding and contracting vapor.

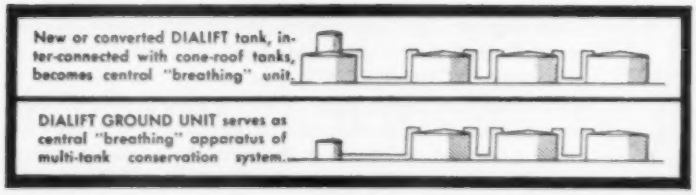
B—Vapor passes to and from tank and DIALIFT through simple elbow connection.

C—DIALIFT and tank have full-rated capacity.

D—Membrane can't come in contact with product.

E—DIALIFT can be isolated for maintenance and inspection, product tank stays in service.

The most efficient and economical vapor conservation system for new or old tanks.


New or converted DIALIFT tank, inter-connected with cone-roof tanks, becomes central "breathing" unit.
DIALIFT GROUND UNIT serves as central "breathing" apparatus of multi-tank conservation system.

THE HAMMOND DIALIFT consists of a gas-tight Vulcalock membrane attached to the inside periphery of a cylindrical metal housing to become a "breathing" apparatus to accommodate the expanding and contracting vapor as developed in product storage tanks. The DIALIFT can be used as a single conservation unit by being attached to the roof of a product storage tank or as a central "breathing" system by being manifolded to a number of product storage tanks. There are two forms of installation:—Ground type manifolded to a number of tanks to form a conservation system and integrated type whereby the DIALIFT is attached to the roof of a tank for vapor conservation for one or a number of tanks. The DIALIFT is completely isolated from the product storage tank. Vapor passes between the tank and DIALIFT through a vaporline connection. It is easy to convert old cone roof tanks to efficient vapor-saving DIALIFT installations by attaching a DIALIFT housing with membrane to the roof of the old tank and connecting the vaporline between the tank and DIALIFT.

THE HAMMOND DIALIFT ELIMINATES BREATHING LOSS AND REDUCES FILLING LOSS

Write for dialift catalog 55DL

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IMPROVED SHELL LPI PROCESS FOR BUTANE ISOMERIZATION IS 5 WAYS BETTER

Shell's Liquid Phase Isomerization
makes it more economical than ever to
convert n-butane to isobutane

NEW PROCESS SCHEME MEANS:

1. highest conversion of any known process
2. lower process plant cost
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For technical details and cost estimate, see your engineering contractor. LPI process is licensed by Shell Development Company, 50 West 50th Street, New York 20, New York.

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DIALIFT

the only membrane type conservation tank

...with full-rated vapor and product capacity at all times

...with a membrane that cannot come in contact with product

...with vapor space that can be isolated for inspection and maintenance without taking tank out of service.

Principle of the Hammond Dialift

A—DIALIFT DIAPHRAGM rises and falls to accommodate expanding and contracting vapor.

B—Vapor passes to and from tank and DIALIFT through simple elbow connection.

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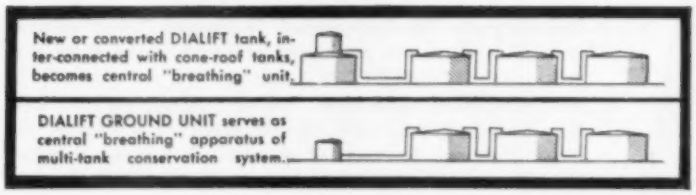
The most efficient and economical vapor conservation system for new or old tanks.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THE HAMMOND DIALIFT ELIMINATES BREATHING LOSS AND REDUCES FILLING LOSS

Write for dialift catalog 55DL

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Steel men at The Youngstown Sheet and Tube Company are dedicated to this principle: teamwork is the essence of prosperity. YOUNGSTOWN steelmakers put this rule to work when they make pipe. Working closely with oil men, they provide Oil Country tubular products that meet the many advanced demands of the modern Petroleum Industry. Oil men the world over and YOUNGSTOWN steel men - - partners in progress, contributing toward an even greater standard of living!

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It's surprising how little oil's customers know about the biggest selling petroleum product—gasoline! They never see it or touch it—yet they *use* it every day. All they know is the price they pay . . . and only a few know how big a bargain they really get with today's gasoline.

You'll be helping yourself and your industry by giving oil's customers the *real* story about today's gasoline prices and taxes. Here are the facts:

Direct Taxes add 40 cents to every dollar spent for today's gasoline!

When you hear the phrase "gasoline prices are high," this is your best reply: "Gasoline *taxes* are high, but gasoline *itself* is a bargain!" Yes, it's true that for every dollar spent for gasoline, an additional 40¢ must be paid for federal and state gasoline taxes!

Mr. Average American Motorist—who drives his car approximately 9,360 miles a year—pays $56.76 in direct taxes on gasoline alone! That's an average of 8.8¢ a gallon—a rate four times higher than the federal 10% tax on "luxuries" like mink coats!

But let's look at the price of gasoline *itself*. Gasoline has gone up only a few pennies, in the last five years. Meanwhile, gasoline quality has improved tremendously, so that today's *regular* gasoline is as good as premium gasoline was only five short years ago. And today's *premium* gasoline is as powerful as the bomber and fighter gasolines of the last war.

So next time you are asked about gasoline prices, remember . . .

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I would like to obtain more information about today's gasoline quality, prices and taxes. Please send me your FREE booklets.

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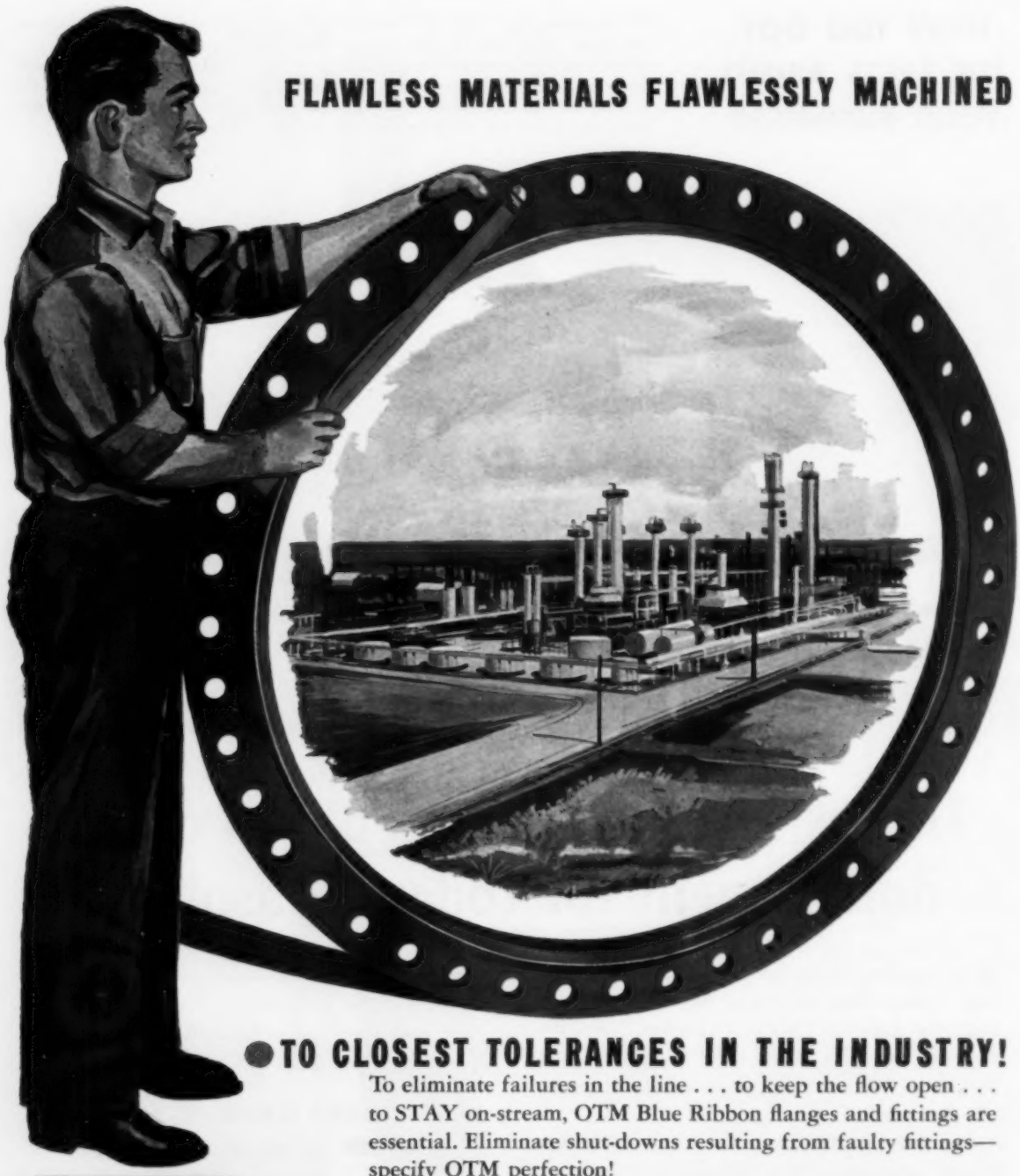

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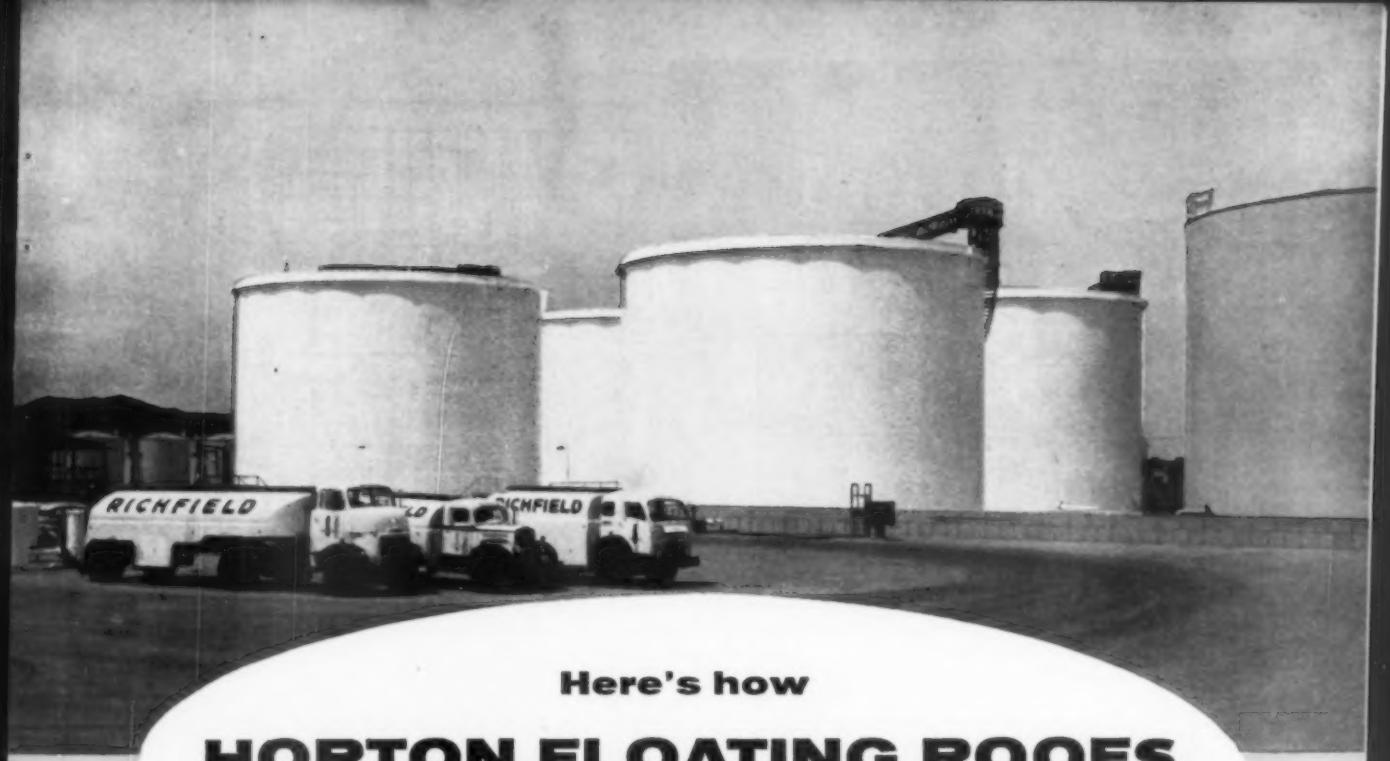


Here's how

HORTON FLOATING ROOFS

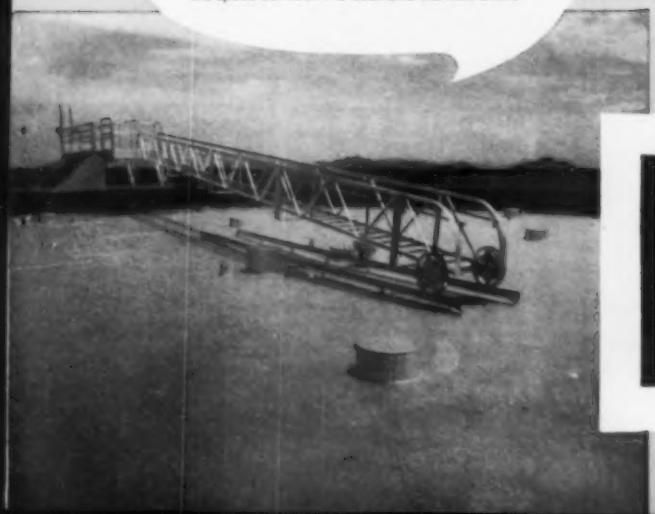
control evaporation loss

at Phoenix terminal

Four storage tanks equipped with Horton® Double-Deck Floating Roofs are reducing evaporation losses, corrosion and fire hazard at the Richfield Oil Corporation's Phoenix, Arizona, terminal on the Southern Pacific Pipe Line. The Horton Floating Roofs float directly on the surface of the liquid in the tanks, eliminating space for air-vapor mixture to form, be vented and lost.

Horton Floating Roofs are built in three types—Double-Deck, Pontoon and Pan. Write our nearest office for further information, estimates or quotations.

Below: View inside one of Richfield Oil Corporation's tanks equipped with a Horton Double-Deck Floating Roof. The Horton Seal around the edge of the roof efficiently closes the space between the deck and the tank shell.



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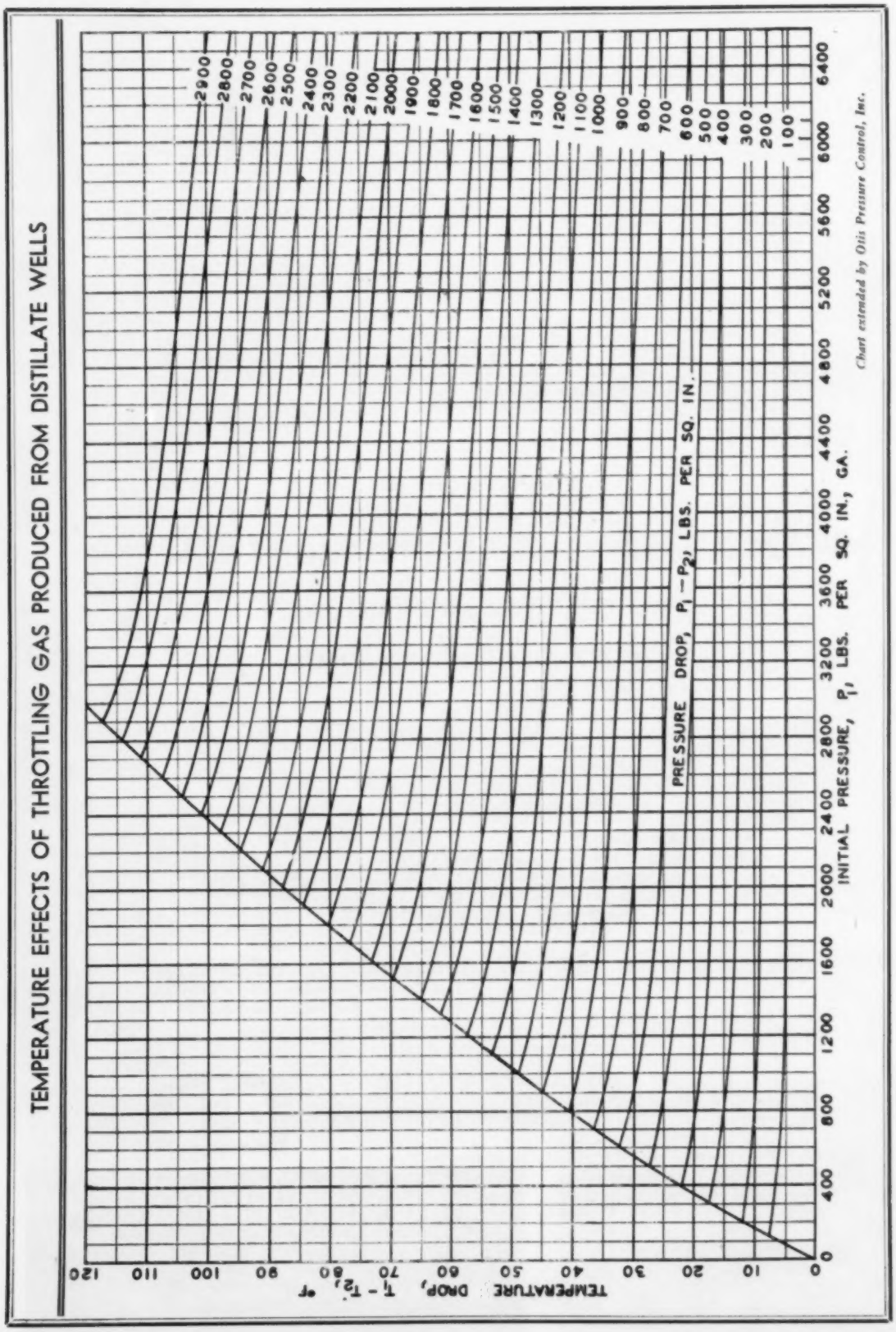
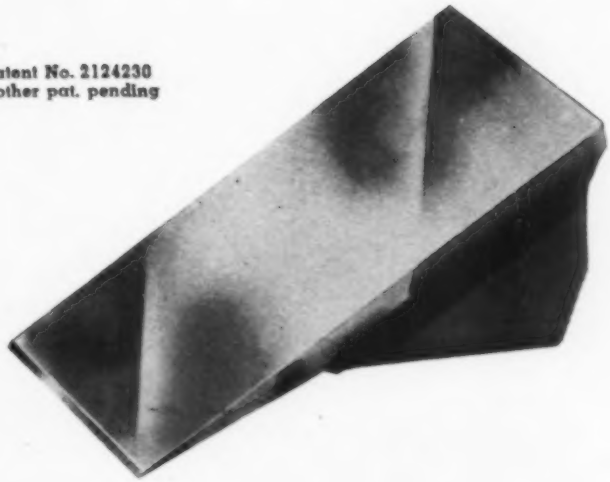

TEMPERATURE EFFECTS OF THROTTLING GAS PRODUCED FROM DISTILLATE WELLS
TEMPERATURE DROP, $T_1 - T_2$, °F
0 10 20 30 40 50 60 70 80 90 100 110 120
INITIAL PRESSURE, P_1, LBS. PER SQ. IN., GA.
0 400 800 1200 1600 2000 2400 2800 3200 3600 4000 4400 4800 5200 5600 6000 6400
PRESSURE DROP, $P_1 - P_2$, LBS. PER SQ. IN.
100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600 2700 2800 2900
Chart extended by Otis Pressure Control, Inc.

Teeth that really dig!

There is no substitute for Rolled Alloy Steel

Patent No. 2124230
& other pat. pending



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Quality craftsmanship is amply demonstrated by Graver skills with automatic aluminum welding equal to ASME X-ray standards. Graver's advanced welding techniques are among the reasons Graver is called upon regularly to fabricate aluminum, alloys and carbon steel into a variety of shop-built and field-erected pressure vessels and storage tanks. It will pay you to inquire about how Graver craftsmanship and experience can be valuable to you, too.

ALLOY DIVISION

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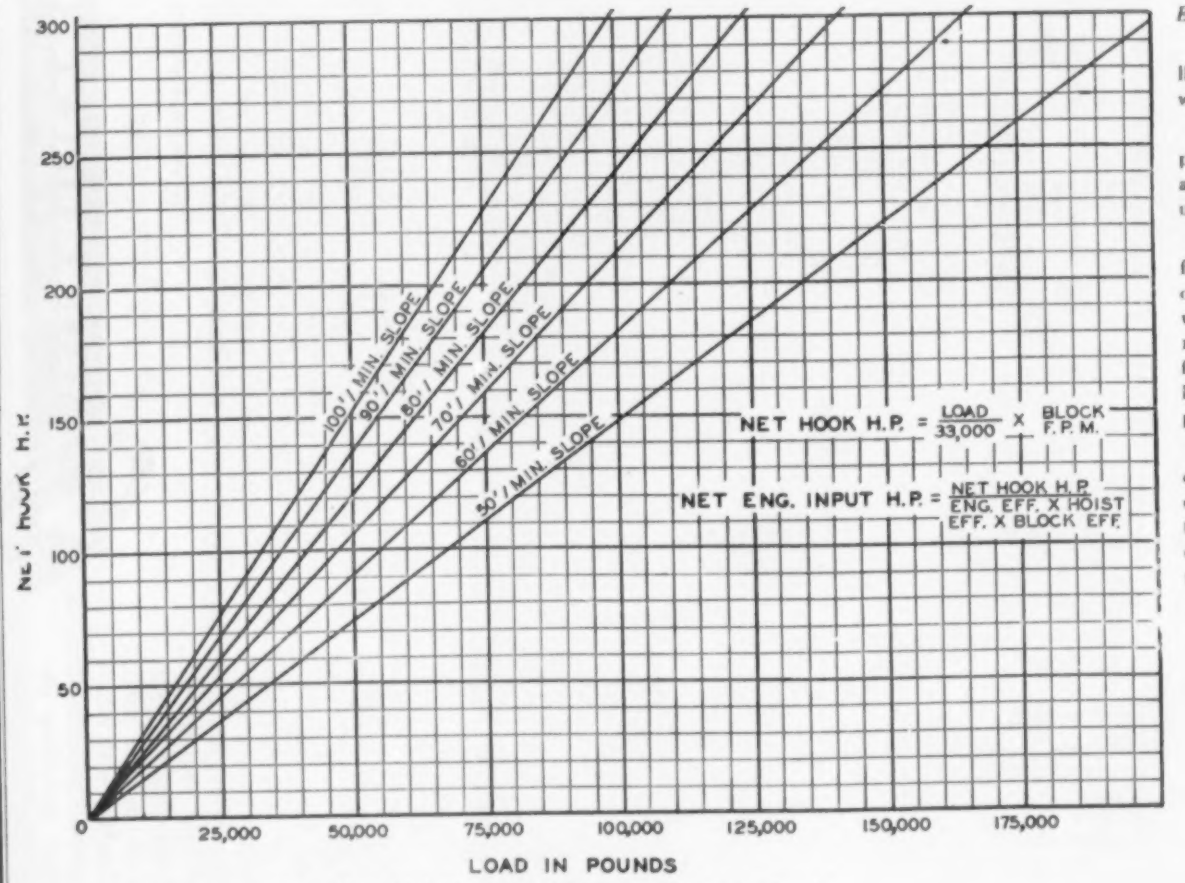
CHART FOR ESTIMATING HORSEPOWER FOR HOISTING



This chart is taken from the article entitled, "Selections of Internal-combustion Engines for Field Use," by James Moon, published in The Petroleum Engineer, September, 1946, page 57.

Example of use:

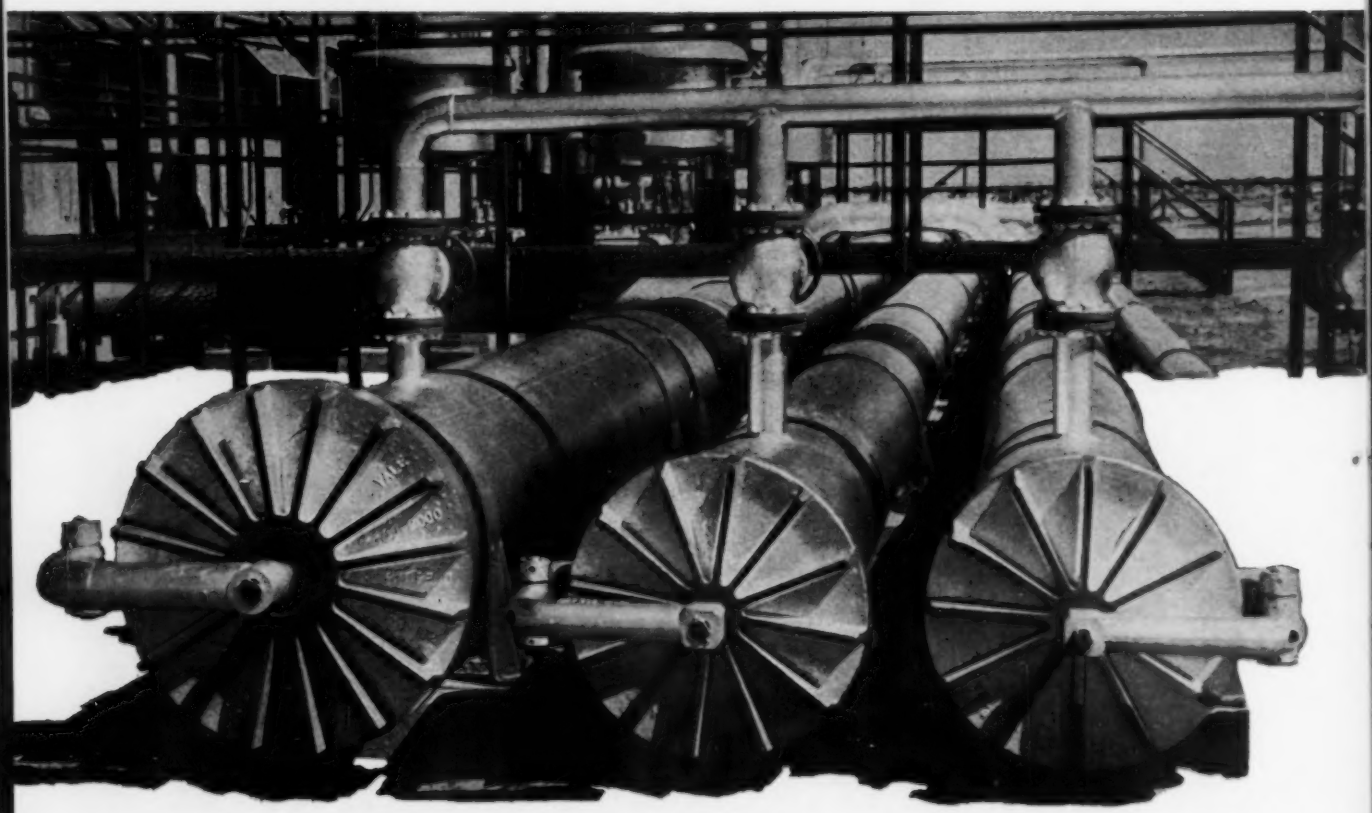
Given: A hook load of 81,000 lb. (10,000 ft. of 2½-in. tubing wet).

Required: The engine horsepower needed to hoist this load at the rate of 90 ft. per min. using a block with 4 lines.

Solution: Enter the chart from the 81,000 lb. load point on the lower scale. Follow upward to the diagonal line marked "90'/min. slope." Then, find the net hook hp. on the left-hand scale opposite the point of intersection = 221 hp.

Assuming the engine efficiency = 85 per cent; the hoist efficiency = 85 per cent; and the block efficiency = 96 per cent; then, the net engine hp. required =

$$\frac{221}{.85 \times .85 \times .96} = 320 \text{ hp.}$$



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The use of 2-Piece Blank Caps on headers, traps, scrapers and blowdowns will effect great savings in **your** systems. They are furnished in every size from 2" through 38", ASA Series 400, 600 and 900. Easy-swinging hinges are available for all sizes, for horizontal or vertical installation. For complete information, write for Catalog No. 56.

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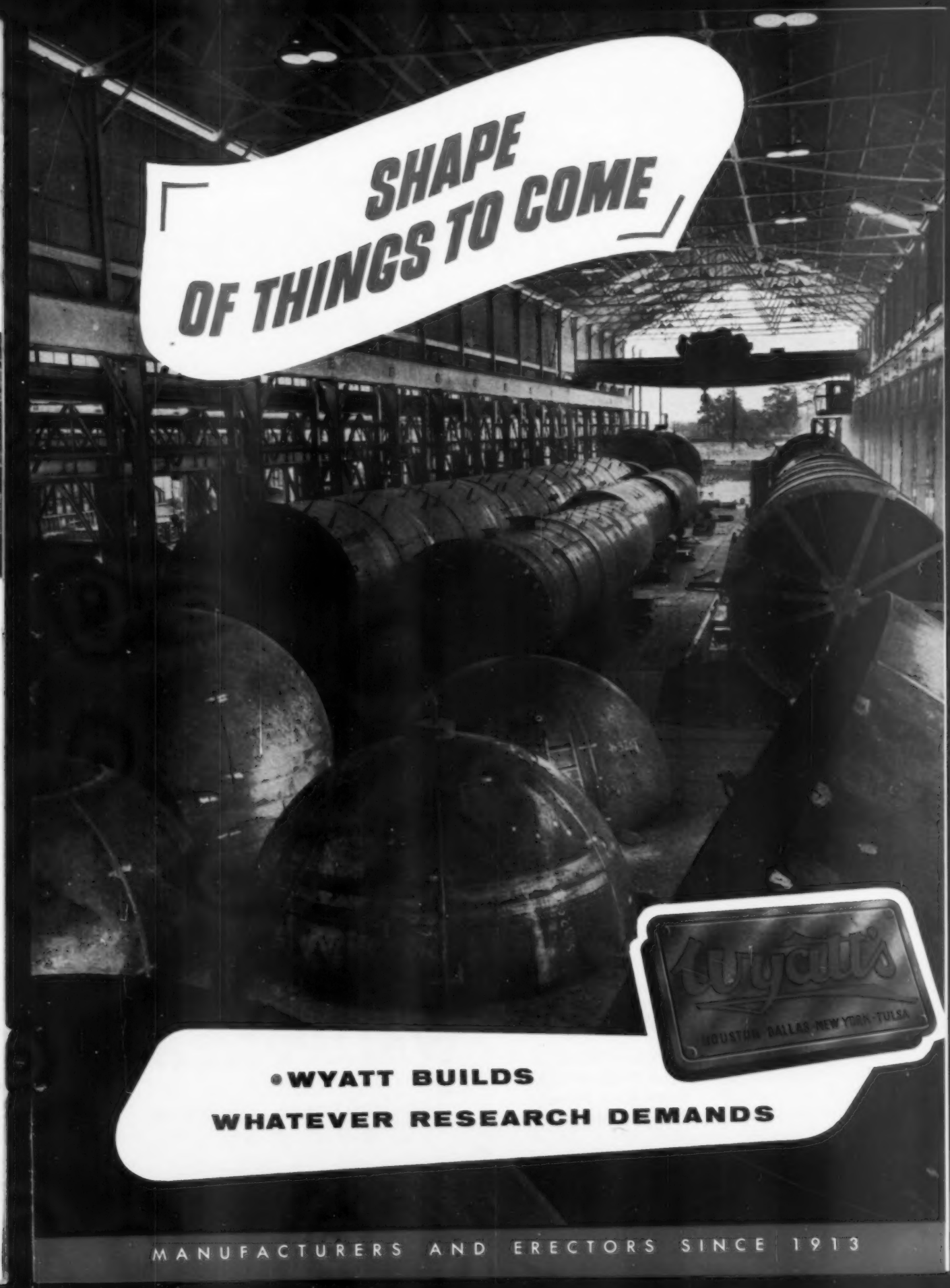
P. O. Box 10192 • Houston, Texas • Telephone ME 5-6418


SHAPE
OF THINGS TO COME
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WHATEVER RESEARCH DEMANDS
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in seconds— instead of minutes

with this timesaving combination

Yes, seconds are all it takes to lubricate plug valves, today. You'll eliminate waste, and save time and effort with this combination: Walworth High Pressure Lubricant Gun, Walworth Button-Head Fittings, and Walworth Jumbo Size Lubricant Sticks. They'll pay for themselves quickly and are adaptable to most of the lubricated plug valves that are in use today.

Walworth High Pressure Lubricant Gun. This is the only gun available today that satisfactorily handles the stick form, full-bodied lubricants needed for proper lubrication and sealing of plug valves. Easy to operate; two Jumbo Size Lubricant Sticks fill the barrel.

Walworth Jumbo Size Lubricant Sticks. Individually wrapped and packed ten to the box; clean and easy to handle . . . eliminate messy loading. Types available for most line fluids. Always use Walworth Lubricants in Walworth Lubricated Plug Valves.

Walworth Button-Head Lubricant Fittings. Use them as lubricant fittings or as regular lubricant screws with standard size lubricant sticks. Just slip hose coupling onto fitting for a leakproof connection.

Start saving today . . . call your nearby Walworth Distributor. He'll be glad to supply Walworth High Pressure Lubricant Guns, Button-Head Fittings, and the right Jumbo Size Lubricant Sticks for any lubricated plug valve service condition.

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Visco® CONSISTENTLY EFFICIENT OIL FIELD CHEMICALS

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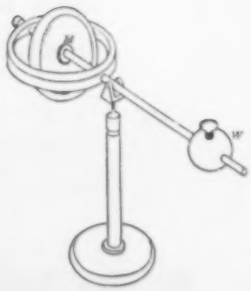
A Teacher affects eternity... he can never tell where his influence stops

. . . wrote historian Henry Brooks Adams—a truth that today demands universal recognition. America is losing to industry many of those best able to inspire and mold youthful minds—the dedicated teachers of high school subjects prerequisite to engineering training.

The value of a teacher's influence in a boy's selection of a career cannot be over-estimated, yet all too often the rewards of teaching are more spiritual than material. Compensation fitting the importance of their work can help keep teachers in their classrooms, where they prefer to be.

America gains every time teaching is chosen as a career. It also gains whenever a teacher finds it possible to remain in the profession.



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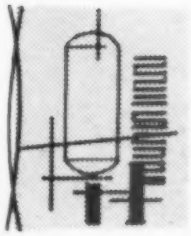
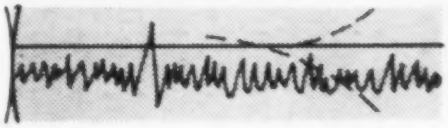
Facilities, personnel, and budgets are expanding at a surprising rate . . . Petroleum industry is low percentagewise but shows growing interest as management finds it can . . .



Reap the Research!



Ernestine Adams

IN research you sow ideas and cultivate and hybridize them. You put in stakes to support them or nip their buds to make them stronger.

Sometimes the harvest is Jack's giant beanstalk on which we climb to higher living standards. Like the synthetic rubber that helped win the war and has given us better tires and tiles for everyday living.

Much more often the crop is a failure — although failures are harder to measure than success for something is gained in every search for truth. What we mean by failure is that perhaps five percent of research ideas are useless. But learning what is useless may be as important as learning what is not.

For larger companies in the petroleum industry research is a necessity.

"While we have much confidence in the future, it has become apparent that organized scientific research is essential and perhaps vital for the survival of any large corporation." So said J. C. Donnell II, president of The Ohio Oil Company, at the dedication of the company's new Research Center in Denver, Colorado.[1]

Expansion Heavy

The last year's increase in facilities and personnel for research and development in the petroleum industry is startling.

Phillips Petroleum added two large laboratories at its Bartlesville, Oklahoma, Center.[2] Gulf Oil expanded its Harmarville, Pennsylvania, Center with three large new laboratories.[3]

Richfield's new research center at Anaheim, California, was built at a cost of $2.7 million. At the end of the year it had approximately 100 employees. The Center is made up of five operating divisions: Fuels, lubricants, organic research, process development, and services.

Standard Oil (Ohio) will dedicate this year its new $2.4 million Chemical and Physical Research Center in Warrensville Heights, a Cleveland suburb. Sohio has for many years had research facilities near two universities but will move activities to the new 87-acre site.

Construction at Humble's Baytown Research Center increased facilities for research in refining and petrochemicals by some 40 percent. An addition to the Houston Research Center will provide 60 percent more space for activities in exploration and production.

Recently Cities Service Research and Development opened its new laboratory on 100 acres adjacent to the New Jersey Turnpike.

Standard Oil (Indiana) is expanding its Whiting, Indiana, facilities with a large pilot plant building and several others.

Caltex completed the 10 laboratories on its program this year. Now it is constructing the Caltex Central Laboratories next to the Pernis refinery in Rotterdam, the Netherlands. Completion is scheduled for mid-1958.

Additional facilities at Esso Research and Engineering, Linden, New Jersey, were completed. Remodeling and construction at Emeryville Research Center provided Shell Oil with more space.

New research laboratories were completed at the Derby refinery of Colorado Oil and Gas Corporation at Wichita, Kansas.

A new wing was added by Atlantic Refining to its Dallas, Texas, laboratories.

Texaco opened two new laboratories at its Beacon, New York, Center and a new analytical laboratory at its Port Arthur, Texas, refinery.

Radiation and Computers

Two tremendous incentives to greater research action are use of atomic radiation and of giant electronic computers.

At least 15 petroleum laboratories are equipped for radioactive projects.

Sinclair has a new Radiation and Tracer laboratory using spent fuel elements from an Atomic Energy Commission reactor as its source of gamma ray radiation.

Construction has begun on Conoco's atomic radiation laboratory at Ponca City, Oklahoma. Cities Service's new radiation laboratory houses a 3000 Curie source of Cobalt 60.

In Gulf's Nuclear Science Laboratory, nuclear energy is supplied by a three-million volt Vande Graaff accelerator in the form of either negatively or positively charged particles.

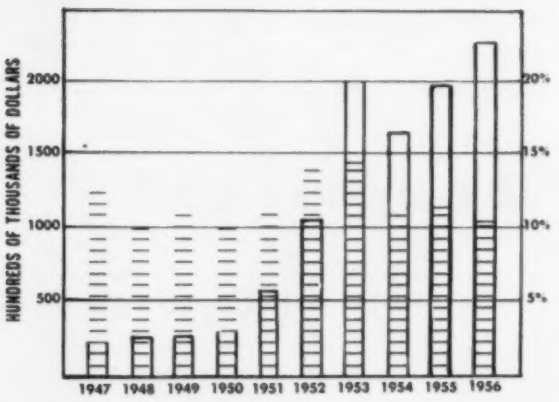
Shell uses the same nuclear energy equipment at Emeryville for both basic knowledge about reactions and for more practical problems.

Atlantic Refining is supplementing its radiation research by installing a miniature oil refinery in the service

Miss Adams is Management Editor

[1] Resources of Mind and Material Are Combined in Ohio Oil Company's New Research Center in Denver, Colorado, page E-12, *The Petroleum Engineer*, November 1956.
[2] 30 Years of Growth Puts Phillips Center Among Top Research Organizations, page E-14, *The Petroleum Engineer*, June 1957.
[3] Three New Laboratories Make Gulf's Research Center One of the World's Largest, page E-21, *The Petroleum Engineer*, July 1, 1957.

Wearing protective goggles, W. Alton Jones, chairman of Cities Service, operates a manipulator used for handling radioactive Cobalt 60 at the company's new product research laboratory at Cranbury, New Jersey. President Burl S. Watson witnesses the demonstration.



RESEARCH, ENGINEERING AND DEVELOPMENT EXPENDITURES

Dollars *Percent of Sales*

facilities of the atomic pile at Brookhaven National Laboratories.

Socony Mobil and nine companies from other industries incorporated to build a nuclear research reactor near Princeton, New Jersey. Now Socony is constructing its own nuclear research laboratory near the reactor site.

Assistant Director Thomas of Sun's Marcus Hook laboratory says atomic radiation holds promise for some petrochemical processes but only speculative possibilities for processing large-volume petroleum products.

Another reason for accelerated research activity is the proved usefulness of computers. They are in wide use now, where three years ago they were rare in petroleum research. Many companies, from experience of giant computers in research, are extending their use to all operations.

Projects Unlimited

As Cities Service puts it: "Research is the key to petroleum progress through the development not only of new and better products but of new and better ways of doing things, from the producing field to the market place."

But the research laboratory is and should be unlimited in ideas. Projects range far and wide.

Kerr-McGee is going into processing of minerals, including uranium and potash.

A full scale demonstration plant for extracting oil from shale in Colorado is Union of California's most significant research project at this time.

Phillips is working on rocket fuels and engines for rockets.

One top research project is research itself. What is it? What will it do for the company?

First job of Ohio Oil's Center was to survey "What had been done in various petroleum research fields, designing and equipping laboratories, studying and formulating plans."

Even before it had a center, Ohio contracted a project with an outside research organization to find out if it should have a research center.

A side product of research is stronger competition. Many companies agree that only with diligent research can they maintain their position in today's market. In describing its new research division and facilities, Richfield Oil reported that these would "insure continuance of the strong competitive position of our present products."

Pure Oil Refining and Development reported "Progress was made in methods for more rapid evaluation of products, particularly important in accelerating experiments and reducing research to practice."

Research has heightened competitive possibilities and has become a major factor in successful operations. It is survival insurance.

It Takes Money

California (Standard) Research increased its budget in 1956 by 15 percent to $15 million. Conoco's 1956 outlays for research went up 18 percent over the year before — to $3.9 million.

Humble spent $8 million last year — up 9 percent. Socony went to $18 million in 1956, one million dollars more than the year before. Esso Research and Engineering expenditures rose to $44 million in 1956, about 12 percent above 1955. Union Oil of California will spend $9 million in 1957 for research and technical service, $2 million more than was spent in 1956.

We estimated research expenditures by oil and gas companies at approximately $225 million in 1955, including new facilities and current expenditures. We believe 1956 will pass that mark by $20 million and 1957 should show a jump to $280 million. Part of this is inflation, which brings higher construction and equipment costs and higher salaries.

This estimate is based on some known research budgets and on number of personnel. We have found a direct and fairly uniform proportion

HOW TO PROFIT FROM RESEARCH

MANAGEMENT must establish a five-point plan for the direction and guidance of research activities.

FIRST, management must set forth the overall company objectives—that is, it should determine the industries or customers to be served, the kinds of business to be pursued, and the types of products to be manufactured or services to be performed.

SECOND, form an organization that will permit top management control of research — whether by means of a New Products Department manned by a full-time staff or a New Products Committee or a Research Advisory Committee composed of executives of various departments.

THIRD, management obviously must provide adequate research and development facilities, well trained and skilled scientists, engineers and other technicians; and sufficient funds to attain the company's research goals.

FOURTH, management must determine or approve the research projects to be undertaken, approve a budget and time schedule for these projects, and constantly re-evaluate them.

FIFTH, provision should be made for a continual interchange of ideas between members of top management, the research organization, and the sales, product engineering, manufacturing, patent and financial departments.

In my company we believe that if we adhere to the points which I have just outlined, profits can be achieved through research. For research today has become big business. But only through the establishment of proper policies and by adequate organization can it be operated as big business.

From "Management's Role in Achieving Profits from Research" by Robert S. Ingersoll, president, Borg-Warner Corporation, presented before National Industrial Research Conference.

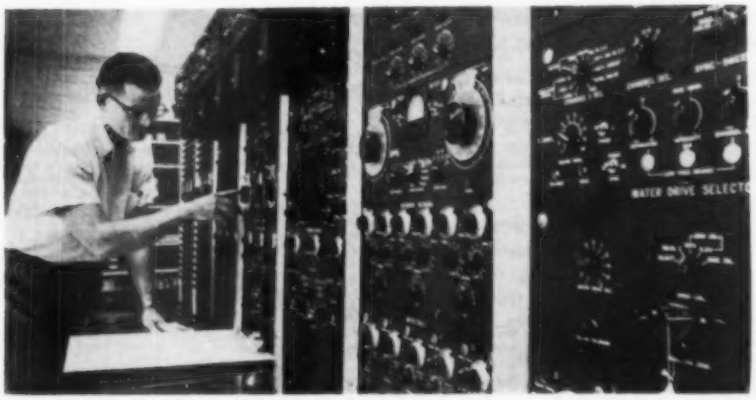
between research expenditures and number of research personnel in the petroleum industry.

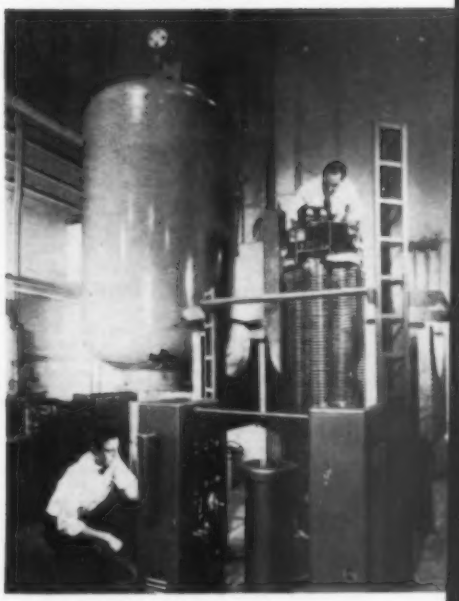
Now $280 million for 1957 looks like a big expenditure but in proportion to percentage of sales petroleum industry research budgets rank pretty low. This is less than one percent of sales.

Dr. John T. Rettaliata, president of Illinois Institute of Technology, estimates that U. S. industry spends about two percent of annual sales for research and development. In rapidly changing technical industries — such as scientific equipment — expenditures range from 5 to 9 percent of sales. (See graph).

The amount spent by petroleum industry supply and service companies for research would be difficult to estimate.

For instance, a large portion of U. S. Steel's extensive research activities affect the petroleum industry. Both its Applied and Fundamental Research Laboratories, and the laboratories of its affiliates, American Steel and Wire, Oil Well Supply, National Tube, and Universal Atlas Cement, work toward solutions that will benefit the petroleum industry as well as others.





New analytical building (above) marks a decade of growth during which the Texaco Research Center has more than doubled its size. Van de Graeff "atom smasher" (right) is in new Nuclear Science Laboratory at Gulf Oil's Research Center. High-speed electronic analyzer (below) at Sun Oil's Production Research and Development Laboratory, Richardson, Texas.

Petrolite recently opened a laboratory in St. Louis[4] devoted almost entirely to our industry. Halliburton Oil Well Cementing has recently expanded its large Research Center. Graver Tank and Manufacturing research works on conservation equipment for the petroleum industry.

These are a very few samples. All large supply and service companies and many small ones are seeking better methods and equipment for petroleum operations.

But there is high return on your research investment. W. Alton Jones, chairman of Cities Service, made this interesting prediction when his company's new lab was opened: *"American industry will spend $20 billion in 1962 for new plant and equipment for new products growing out of 1957 research alone."*

[4] Research Feeds Petrolite Progress, *The Petroleum Engineer*, page E-11, July 15, 1957.

Wanted: Researchers

Considering the so-called acute shortage of scientific minds, research staffs have done well. At a time when operations call for more engineers and technicians than available, it is interesting that research employees have gained steadily in numbers.

Standard of California calls it a significant fact that one in 30 of all its employees is engaged directly in research and technical services. In Standard Indiana research operations, 1718 scientists and technicians are employed. Jersey Standard has more than 2900 persons in research work.

There is a wide range of non-technical personnel compared to technical among oil companies but the average is about 40 percent non-technical.

Last year we estimated 18,500 people — scientific, technical and non-technical — were employed in petroleum research. The number probably rose to 20,800 in 1956 and is continuing to increase.

D. Swan, Director of Research for Metals Research Laboratories, stated recently, "Today about 25 percent of all our scientists and engineers are engaged in research and development activities. Not only that, the majority of those left are working in the plants which are the output of the original research activity."

With some crystal-gazing, he brought out this prediction:

"We have not learned yet to adapt on a big scale the techniques so successfully used by our physical scientists to settle the more basic problems of human nature. For example, we haven't really learned how to get along with one another as successfully as I think we can, and without question big strides will be made in adapting experimental techniques (research) to the so-called life sciences, the problems of human relations. This certainly could result in increased productivity. This would result in increasing the standard of living even more than we have been able to achieve so far." ★ ★ ★

Short Course for Research Writers

C. D. Graham, Jr.
Alloy Studies, General Electric Company
Schenectady, New York

Introduction

IT has long been known that . . . I haven't bothered to look up the original reference.

. . . of great theoretical and practical importance . . . interesting to me.

While it has not been possible to provide definite answers to these questions . . . The experiments didn't work out, but I figured I could at least get a publication out of it.

Experimental Procedure

The W-Pb system was chosen as especially suitable to show the predicted behavior . . . The fellow in the next lab had some already made up.

High-purity . . . Very high purity . . . Extremely high purity . . . Super-purity . . . Spectroscopically pure . . . Composition unknown except for the exaggerated claims of the supplier.

A fiducial reference line . . . A scratch.

Three of the samples were chosen for detailed study . . . The results on the others didn't make sense and were ignored.

. . . accidentally strained during mounting . . . dropped on the floor.

. . . handled with extreme care throughout the experiments . . . not dropped on the floor.

. . . given a homogenizing anneal . . . oxidized.

Results

Typical results are shown . . . The best results are shown.

Although some detail has been lost in reproduction, it is clear from the original micrograph that . . . It is impossible to tell from the micrograph.

Presumably at longer times . . . I didn't take time to find out.

The agreement with the predicted curve is excellent . . . fair.

good . . . poor.

satisfactory . . . doubtful.

fair . . . imaginary.

. . . as good as could be expected considering the approximations made in the analysis . . . non-existent.

These results will be reported at a later date . . . I might possibly get around to this sometime.

The most reliable values are those of Jones . . . He was a student of mine.

Discussion

It is suggested that . . . It is believed that . . . It may be that . . . I think.

It is generally believed that . . . A couple of others guys think so too.

It might be argued that . . . I have such a good answer to this objection that I shall now raise it.

It is clear that much additional work will be required before a complete understanding . . . I don't understand it.

Unfortunately, a quantitative theory to account for these effects has not been formulated . . . Neither does anybody else.

Correct within an order of magnitude . . . wrong.

It is to be hoped that this work will stimulate further work in the field . . . This paper isn't very good, but neither are any of the others on this miserable subject.

Acknowledgments

Thanks are due to Joe Glotz for assistance with the experiments and to John Doe for valuable discussions . . . Glotz did the work and Doe explained what it meant. ★ ★ ★

This amusing poke at the researching business is reprinted from Metal Progress, American Society for Metals publication, for May 1957. Editor is E. E. Thum.

Instruments and Control Equipment DIRECTORY

THE PETROLEUM ENGINEER initiated this directory in 1955. Listed below are the names of all the leading manufacturers that produce instruments and control equipment used in the petroleum industry. There are approximately 175 manufacturers, 60 percent more than last year.

In the pages that follow instruments and control equipment are listed under four branches of the industry, (1) Exploration, Drilling, Producing; (2) Refining and Processing; (3) Oil & Gas Pipelining; (4) Research. Under each piece of equipment are the names of companies that manufacture that particular item.

Every oil and gas company today is interested in the possibility of greater automation. This directory will prove valuable to those who need a quick reference of instruments for specific operations.

This is another unique service feature of THE PETROLEUM ENGINEER.

Manufacturers of instruments and control equipment used in petroleum operations

A-1 Bit & Tool Co., Inc., 9000 Alameda Rd., Houston, Texas
Allegany Instrument Co., 1091 Wills Mountain, Cumberland, Md.
American Instrument Co., Inc., 8050-30 Georgia Ave., Silver Spring, Md.
American Kloeckner-Moeller Corp., 4113 East 11th St., Tulsa 12, Okla.
American Machine & Metals, Inc., Gauge Div., Sellersville, Pa.
American Meter Co., 1513 Race St., Philadelphia 2, Pa.
Askania Regulator Co., 240 E. Ontario, Chicago 11, Ill.
Associated Research, Inc., 3758 W. Belmont Ave., Chicago 18, Ill.
Automatic Switch Co., Hanover Rd., Florham Park, N. J.
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio
Baldwin-Lima-Hamilton Corp., Electronics & Instrumentation Div., 42 Fourth Ave., Waltham 54, Mass.
Barkadale Valves, 5125 Alcoa Ave., Los Angeles 58, Calif.
Baroid Div., National Lead Co., P. O. Box 1675, Houston, Texas
Barton Instrument Corp., 580 Monterey Pass Rd., Monterey Park, Calif.
Beckman Instruments, Inc., Scientific Instruments Div., 2500 Fullerton Rd., Fullerton, Calif.
Bendix Aviation, Pacific Div., 11600 Sherman Way, North Hollywood, Calif.
Bettis Corp., P. O. Drawer 9365, Houston, Texas
B-I-F Industries, Inc., 345 Harris Ave., Providence 1, R. I.
BJ Electronics, Borg-Warner Corp., P. O. Box 1679, Santa Ana, Calif.
Black, Sivalls & Bryson, Inc., 7500 E. 12th St., Kansas City 26, Mo.
S. R. Bowen Co., P. O. Box 427, Santa Fe Springs, Calif.
The Bristol Co., Waterbury 20, Conn.
Brooks Rotameter, P. O. Box 432, Lansdale, Pa.
Camco, Inc., P. O. Box 14484, Houston 21, Texas
Cameron Iron Works, Inc., P. O. Box 1212, Houston 1, Texas
A. W. Cash Co., P. O. Box 551, Decatur, Ill.
Central Scientific Co., 1700 Irving Park Rd., Chicago 13, Ill.
Conoflow Corp., 2100 Arch St., Philadelphia 3, Pa.
Consolidated Electrodynamics Corp., 300 N. Sierra Madre Villa, Pasadena, Calif.
Crosby Valve & Gage Co. and The Ashton Valve Co., 43 Kendrick St., Wrentham, Mass.
Cutler-Hammer, Inc., 315 N. 12th St., Milwaukee 1, Wisc.
Dale Co., 1237 W. 15th St., Long Beach 13, Calif.
Daniel Orifice Fitting Co., P. O. Box 19097, Houston 24, Texas
Daytronic Corp., 216 S. Main St., Dayton 2, Ohio
Delsen Corp., 719 W. Broadway, Glendale 4, Calif.
Eagle Signal Corp., Moline, Ill.
Eastman Oil Well Survey Co., Box 1500, Denver, Colo.
Louis C. Eitzen Co., Inc., 17 W. 60th St., New York 23, N. Y.
The Electric Auto-Lite Co., Industrial Thermometer Div., P. O. Box 931, Toledo 7, Ohio
ElectroData, Div. of Burroughs Corp., 460 Sierra Madre Villa, Pasadena, Calif.
EPSCO, Inc., 588 Commonwealth Ave., Boston 15, Mass.
Ercona Corp., 551 Fifth Ave., New York 17, N. Y.
ESCO Manufacturing Co., P. O. Box 1039, Greenville, Texas
Excel Electric Service Co., Inc., 2113 South Western Ave., Chicago 8, Ill.
Falstrom Co., 37 Falstrom Court, Passaic, N. J.
Farris Engineering Corp., 400 Commercial Ave., Palisades Park, N. J.
Fenwal, Inc., Pleasant St., Ashland, Mass.
Fischer & Porter Co., 860 Warminster Rd., Hatboro, Pa.
Fish-Schurman Corp., 70 Portman Rd., New Rochelle, N. Y.
Fisher Governor Co., Box 307, Marshalltown, Iowa
Fisher Scientific, 717 Forbes St., Pittsburgh 19, Pa.
Foster Engineering Co., 835 Lehigh Ave., Union, N. J.
The Foxboro Co., Foxboro, Mass.
Gadco Products, Inc., Box 1211, Long Beach, Calif.
Gardner Laboratory, P. O. Box 5728, Bethesda 14, Md.
Gerrett Oil Tools, Inc., P. O. Box 2427, Longview, Texas
General Controls Co., 801 Allen Ave., Glendale 1, Calif.
General Electric Co., Apparatus Sales Div., 1 River Rd., Schenectady 5, N.Y.
General Precision Laboratory, Inc., 63 Bedford Rd., Pleasantville, N. Y.
The Guiberson Corp., P. O. Box 1106, Dallas 21, Texas
Gulf Coast Machine & Supply Co., P. O. Drawer 1150, Beaumont, Texas
Halliburton Oil Well Cementing Co., Duncan, Okla.
Hallikainen Instruments, 1341 Seventh St., Berkeley 10, Calif.
The Hammarlund Mfg. Co., Inc., 460 W. 34th St., New York 1, N. Y.
Hammel-Dahl Co., Warwick Industrial Park, Providence 5, R. I.
The Hays Corp., 742 E. 8th St., Michigan City, Ind.
Helicoid Gage Div., American Chain & Cable Co., Inc., Bridgeport 2, Conn.
Hewlett-Packard Co., 275 Page Mill Rd., Palo Alto, Calif.
Industrial Instruments, Inc., 89 Commerce Rd., Cedar Grove, N. J.
Jerguson Gage & Valve Co., Adams St., Burlington, Mass.
The Jordan Co., Inc., 3235 W. Hampton Ave., Milwaukee 9, Wisc.
Keystone Development Corp., 2813 Westheimer Rd., Houston, Texas
Kin Tel, Div. of Cohu Electronics, Inc., 5725 Kearny Villa Rd., San Diego 11, Calif.
Kobe, Inc., 3040 E. Slauson Ave., Huntington Park, Calif.
Labline, Inc., 3070-82 W. Grand Ave., Chicago 22, Ill.
Laboratory Equipment Corp., Box 151, St. Joseph, Mich.
Leeds & Northrup Co., 4970 Stenton Ave., Philadelphia 44, Pa.
Lenox Instrument Co., 2010 Chancellor St., Philadelphia 3, Pa.
Leslie Co., Delafield Ave., Lyndhurst, N. J.
Librascope, Inc., 808 Western Ave., Glendale, Calif.
Line Scale Co., Inc., 2734 S. High, Oklahoma City, Okla.
Liquidometer Corp., Skillman Ave., 36th and 37th Sts., Long Island City 1, N. Y.
L-K Pump Valve Co., P. O. Box 901, Houston, Texas
J. E. Lonergan Co., 2nd & Race Sts., Philadelphia 6, Pa.
McCullough Tool Co., 5820 S. Alameda St., Los Angeles 58, Calif.
Macco Oil Tool Co., Inc., 1521 Prince St., Houston 8, Texas
Magnetrol, Inc., 2110 S. Marshall Blvd., Chicago 23, Ill.
Manning, Maxwell & Moore, Inc., 250 E. Main St., Stratford, Conn.
Marsh Instrument Co., Skokie, Ill.
Martin-Decker Corp., 3431 Cherry Ave., Long Beach 7, Calif.
Mason-Neilan Regulator Co., 1204 Adams St., Boston 24, Mass.
The Mercoid Corp., 4201 Belmont Ave., Chicago 41, Ill.
Meriam Instrument Co., 10920 Madison Ave., Cleveland 2, Ohio
Merla Tool Corp., P. O. Box 2576, Dallas 21, Texas
Midwestern Instruments, 41st & Sheridan Rd., Tulsa, Okla.
Milton Roy Co., 1300 E. Mermaid Lane, Philadelphia 18, Pa.
Mine Safety Appliances Co., 201 N. Braddock Ave., Pittsburgh 8, Pa.
Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne & Windrim Aves., Philadelphia 44, Pa.
Multi-Amp Corp., 465 Lehigh Ave., Union, N. J.
Neptune Meter Co., 19 W. 50th St., New York 20, N. Y.
Norwood Controls, Unit of Detroit Controls, Div. of American Steel, 934 Washington St., Norwood, Mass.
Nuclear Development Corp. of America, 5 New St., White Plains, N. Y.
Oil Metering & Processing Equipment Corp., 4843 Yale St., Houston 18, Tex.
Oil Well Supply Div., U. S. Steel Corp., 2001 N. Lamar, Dallas, Texas
Otis Engineering Corp., P. O. Box 7206, Dallas, Texas
Palmer Thermometers, Inc., 2501 Norwood Ave., Cincinnati 12, Ohio
Panellit, Inc., 7401 N. Hamlin Ave., Skokie, Ill.
Penn Instruments Div., Burgess-Manning Co., 4110 Haverford Ave., Philadelphia 4, Pa.
The Perkin-Elmer Corp., Main Ave., Norwalk, Conn.
The Permutit Co., 50 W. 44th St., New York 36, N. Y.
Peschel Electronics, Inc., 13 Garden St., New Rochelle, N. Y.
Petroleum Instrument Co., P. O. Box 6252, Houston 6, Texas
Philips Electronics, Inc., 750 S. Fulton Ave., Mount Vernon, N. Y.
Photovolt Corp., 95 Madison Ave., New York 16, N. Y.
Powers Regulator Co., 3434 Oakton St., Skokie 37, Ill.
Radio Corporation of America, Camden 2, N. J.
The Ramo-Wooldridge Corp., 5730 Arbor Vitae St., Los Angeles 45, Calif.
Raytheon Manufacturing Co., 100 River St., Waltham 54, Mass.
Refinery Supply Co., 621 E. 4th St., Tulsa 3, Okla.
Republic Flow Meters Co., 2240 W. Diversey Ave., Chicago 47, Ill.
Research Appliance Co., Rt. 8 and Craighead Rd., Allison Park, Pa.
Research Controls, Box 5035, Tulsa, Okla.
Rheem Electronics Div., 7777 Industry Ave., Rivera, Calif.

Robertshaw-Fulton Controls, Fielden Instruments Div., 2920 N. 4th St., Philadelphia 33, Pa.
Robinson Orifice Fitting Co., 2830 Lugo St., Los Angeles 23, Calif.
Robinson Orifice Fitting Co. of Texas, P. O. Box 17216, Houston, Texas
Rochester Mfg. Co., Inc., 100 Rockwood St., Rochester 10, N. Y.
Rockwell Mfg. Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.
Rockwell Register Corp., Instruments Div., 510 S. Lansing Ave., Tulsa 10, Okla.
Rolo Mfg. Co., P. O. Box 6763, Houston 5, Texas
R-P&C Valve Div., American Chain & Cable Co., Inc., Tulpehockem St. & L.V.R.R., Reading, Pa.
Ruska Instrument Corp., 4607 Montrose Blvd., Houston 6, Texas
Sanborn Co., 175 Wyman St., Waltham 54, Mass.
Schutte & Koerting Co., Cornwell Heights, Bucks County, Pa.
Scientific Glass Apparatus Co., Inc., 100 Lakewood Terrace, Bloomfield, N.J.
Servo Corp. of America, 20-20 Jericho Turnpike, New Hyde Park, L. I., N.Y.
Servonic Instruments, 1145 S. Fair Oaks Ave., Pasadena 2, Calif.
Shand & Jurs Co., Carleton & 8th Sts., Berkeley 10, Calif.
Southwestern Industrial Electronics Co., 2831 Post Oak Rd., Houston 19, Texas
Sperry-Sun Well Surveying Co., 3118 Blodgett Ave., Houston 4, Texas
Standard Electric Time Co., 89 Logan St., Springfield 2, Mass.
Statham Development Corp., 12411 W. Olympic Blvd., Los Angeles, 64, Calif.
Stromberg-Carlson Co., Div. of General Dynamics Corp., Rochester 3, N. Y.
The Superior Electric Co., 83 Laurel St., Bristol, Conn.
The Swartwout Co., 18511 Euclid Ave., Cleveland 12, Ohio
Taylor Instrument Companies, 95 Ames St., Rochester 1, N.Y.
Technical Oil Tool Corp., 1057 N. La Brea Ave., Los Angeles 27, Calif.
Tenney Engineering, Inc., 1090 Springfield Rd., Union, N. J.
Testing Machines, Inc., 123 W. 64th St., New York 23, N. Y.
Texas Instruments, 6000 Lemmon Ave., Dallas, Texas
Tracerlab, Inc., 1601 Trapelo Rd., Waltham 54, Mass.
Trinity Equipment Corp., 472 Westfield Ave., E. Roselle Park, N. J.
Ultra-Violet Products, Inc., 5114 Walnut Grove Ave., San Gabriel, Calif.
U. S. Electrical Motors, Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.
Universal Atomics, Div. of Universal Transistor Products Corp., 143 E. 49th St., New York 17, N. Y.
Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.
Veeder-Root, Inc., 70 Sargeant, Hartford 2, Conn.
Vernon Tool Co., Ltd., 1101 Meridian Ave., Alhambra, Calif.
Victory Engineering Corp., P. O. Box 573, Union, N. J.
Visco-Meter Corp., 315 Grote St., Buffalo 7, N. Y.
Wallace & Tiernan, Inc., 25 Main St., Belleville 9, N. J.
The Warren Mfg. Co., Inc., New own Rd., Littleton, Mass.
Watts Regulator Co., Lawrence, Mass.
Weksler Thermometer Corp., 195 E. Merrick Rd., Freeport, L. I., N. Y.
Well Instrument Developing Co., P. O. Box 282, Bellaire, Tex.
West Instrument Corp., 4363 W. Montrose Ave., Chicago 41, Ill.
Westinghouse Air Brake Co., Industrial Products Div., Box 36, Wilmerding, Pa.
Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark 12, N. J.
Westronics, Inc., 3605 McCart, Fort Worth 10, Texas
Wheelco Instruments Div., Barber-Colman Co., 1300 Rock St., Rockford, Ill.
Yarnall-Waring Co., 102 E. Mermaid Lane, Philadelphia 18, Pa.

Instruments and Control Equipment Used in EXPLORATION, DRILLING, PRODUCTION

Automatic Drilling & Recording
Martin-Decker
Oil Well Supply

Automatic Lease Control
Fisher Governor
Rolo Mfg.

BS&W Controllers
Foxboro
Garrett Oil Tools

Chemical Feeders
B-I-F Industries
Black, Sivalls & Bryson
Fischer & Porter
Macco Oil Tool
Milton Roy
Research Appliance
Wallace & Tiernan

Controllers, Regulators
ELECTRONIC
Automatic Switch
Bristol
Cutler-Hammer
Fischer & Porter
Garrett Oil Tools
Jordan
Leeds & Northrup
Manning, Maxwell & Moore
Minneapolis-Honeywell
Peschel Electronics
Rheem Electronics
S'west'n Ind. Electron.
Statham Development
Vapor Recovery Systems
Weston Electrical
Westronics
Wheelco Instruments

PNEUMATIC
Barksdale Valves
Barton Instrument
Bettis
Black, Sivalls & Bryson
Bristol
A. W. Cash
Conoflow
Fischer & Porter
Fisher Governor
Foxboro
Garrett Oil Tools
Guiberson
Leeds & Northrup
Magnetrol
Merla Tool
Minneapolis-Honeywell
Powers Regulator
Republic Flow Meters
Research Controls
Vapor Recovery Systems
Watts Regulator
Westinghouse Air Brake
Weston Electrical

Control Transmission Systems
Bendix, Pacific Div.
BJ Electronics
Bristol

ELECTRONIC
Fischer & Porter
Fisher Governor
Foster Engineering
Garrett Oil Tools
Hammarlund Mfg.
Hewlett-Packard
Manning, Maxwell & Moore
Minneapolis-Honeywell
Reliance & Elec. Eng.
Robertshaw-Fulton
Shand & Jurs
S'west'n Ind. Electron.
Statham Development
Stromberg-Carlson
Wheelco Instruments

HYDRAULIC
Askania Regulator
Cameron Iron Works
Fischer & Porter
Foster Engineering
Gadco Products
General Controls
Hammel-Dahl
Martin-Decker
Mason-Neilan

PNEUMATIC
American Mach. & Metals
American Meter
Barton Instrument
B-I-F Industries
Black, Sivalls & Bryson
Bristol
Cameron Iron Works
Fischer & Porter
Fisher Governor
Foster Engineering
Foxboro
Garrett Oil Tools
General Controls
Hammel-Dahl
Mason-Neilan
Minneapolis-Honeywell
Oil Metering & Process.
Republic Flow Meters
Research Controls
Taylor Instrument
Westinghouse Air Brake

Data Logging
EPSCO

Electric-Power Controls
Am. Kloeckner-Moeller
Automatic Switch
Cutler-Hammer
ESCO
General Electric
Peschel Electronics
Raytheon Mfg.

Flow Meters
DRY TYPE
American Meter
Barton Instrument
Bristol
Foxboro
Minneapolis-Honeywell
Oil Metering & Process.
Penn Instruments
S'west'n Ind. Electron
Taylor Instrument

FULL BORE
Fischer & Porter
Foster Engineering

MASS FLOW
Fischer & Porter
Norwood Controls
Penn Instruments
S'west'n Ind. Electron.

ORIFICE
Barton Instrument
B-I-F Industries
Bristol
Daniel Orifice Fitting
Fischer & Porter
Foxboro
Meriam Instrument
Minneapolis-Honeywell
Oil Metering & Process.
Penn Instruments
Republic Flow Meters
Robinson Orifice Fitting
Robinson Orifice of Tex.
Rockwell Register
S'west'n Ind. Electron.

REMOTE INDICATION AND INTEGRATION
American Meter
Barton Instrument
Bendix, Pacific Div.
B-I-F Industries
BJ Electronics
Bristol
Brooks Rotameter
Fischer & Porter
Foxboro
Hallikainen Instruments
Jordan
Librascope
Mason-Neilan
Minneapolis-Honeywell
Norwood Controls
Oil Metering & Process.
Penn Instruments
Republic Flow Meters
Rockwell Register
S'west'n Ind. Electron.
Taylor Instrument

Flow Recorders
ELECTRICAL
B-I-F Industries
Bristol
Fischer & Porter
Foxboro
Leeds & Northrup
Manning, Maxwell & Moore
Minneapolis-Honeywell
Oil Metering & Process.
Penn Instruments
Republic Flow Meters
S'west'n. Ind. Electron.
Westronics

MECHANICAL
American Meter
Barton Instrument
B-I-F Industries
Bristol
Dale Co.
Fischer & Porter
Foxboro
Hallikainen Instruments
Mason-Neilan
Minneapolis Honeywell
Neptune Meter
Oil Metering & Process.
Penn Instruments
Petroleum Instrument
Taylor Instrument

Gas Indicators & Analyzers
Baroid, National Lead
Beckman Instruments
Consolidated Elec'dynam.
Fischer & Porter
Hallikainen Instruments
Leeds & Northrup
Mine Safety Appliances
Minneapolis-Honeywell
Perkin-Elmer
Permutit
Petroleum Instrument
R-P&C Valve Div.
S'west'n. Ind. Electron.

Geological
American Instrument
Ultra-Violet Products

Gravitometers
Fisher Scientific
Hallikainen Instruments
Minneapolis-Honeywell
Refinery Supply
Texas Instruments

Intermitter Controls
Black, Sivalls & Bryson
Camco, Inc.
Fisher Governor
Guiberson
Macco Oil Tool
Merla Tool
Taylor Instrument

Liquid Level Gages
ELECTRONIC
Baldwin-Lima-Hamilton
BJ Electronics
Bendix, Pacific Div.
Bristol
Fischer & Porter
Fisher Governor
Keystone Development
Manning, Maxwell & Moore
Minneapolis-Honeywell
Penn Instruments
Robertshaw-Fulton
Shand & Jurs
Texas Instruments
Vapor Recovery Systems
Victory Engineering

MECHANICAL
Barton Instrument
Bendix, Pacific Div.
Bristol
Crosby-Ashton
Fischer & Porter
Foxboro
Ferguson Gage & Valve
Manning, Maxwell & Moore
Minneapolis-Honeywell
Norwood Controls
Penn Instruments
Shand & Jurs
Vapor Recovery Systems
Wallace & Tiernan

PNEUMATIC
Barton Instrument
B-I-F Industries
Black, Sivalls & Bryson
Bristol
Brooks Rotameter
Crosby-Ashton
Fischer & Porter
Fisher Governor
Foxboro
Meriam Instruments
Minneapolis-Honeywell
Republic Flow Meters
Rochester Mfg.
Vapor Recovery Systems
Wallace & Tiernan

Mud Testing
Baroid, National Lead
Perkin-Elmer
Photovolt
Petroleum Instrument
Ultra-Violet Products

pH-Indicators, Recorders, Controllers
Baroid, National Lead
Beckman Instruments
Bristol
Fischer Scientific
Foxboro
General Electric
Leeds & Northrup
Manning Maxwell & Moore
Minneapolis-Honeywell
Photovolt
Robertshaw Fulton
Wallace & Tiernan
Weston Electrical
Wheelco Instrument

Pressure
GAGES
American Instrument
Am. Machine & Metals
American Meter
Baldwin-Lima-Hamilton
BJ Electronics
Cameron Iron Works
Consolidated Elec'dynam.
Fischer & Porter
Foxboro
General Controls
Helicoid Gage Div.
Line Scale
J. E. Lonergan
Manning, Maxwell & Moore
Marsh Instrument
Martin-Decker
Minneapolis-Honeywell
Norwood Controls
Rochester Mfg.
Servonic Instruments
Statham Development
Taylor Instrument
Wallace & Tiernan
Weksler Thermometer

MECHANICAL RECORDERS
Barton Instrument
B-I-F Industries
Bristol
Consolidated Elec'dynam.
Crosby-Ashton
Fischer & Porter
Foxboro
Penn Instruments
Martin-Decker
Weston Electrical
Minneapolis-Honeywell
Weksler Thermometer

REMOTE READING RECORDERS
Barton Instrument
Bendix, Pacifi Div.
B-I-F Industries
Bristol
Consolidated Elec'dynam.
Fischer & Porter
Foxboro
Leeds & Northrup
Librascope
Martin-Decker
Minneapolis-Honeywell
Penn Instruments
Republic Flow Meters
Shand & Jurs
Weksler Thermometer
Weston Electrical

SWITCHES
Barksdale Valves
Bristol
Cutler-Hammer
General Electric
Minneapolis-Honeywell
Servonic Instruments

Production Testing Equipment
American Instrument
Baldwin-Lima-Hamilton
Bendix, Pacific Div.

Fisher Scientific
Guiberson
Minneapolis-Honeywell
Oil Metering & Process
Peschel Electronics
Rolo Manufacturing

Seismograph Instruments
Minneapolis-Honeywell
S'west'n Ind. Electron
Texas Instruments

Speed Controllers
Askania Regulator
B-I-F Industries
Bristol
Cutler-Hammer
Foxboro
Jordon
Leeds & Northrup
Minneapolis-Honeywell
Taylor Instruments

Surveying Equipment
Ercona
Minneapolis-Honeywell
Technical Oil Tool
Universal Atomics
Wallace & Tiernan

Tachometers
Associated Research
Bristol
Louis C. Eitzen
Foxboro
General Electric
Hewlett-Packard
Martin-Decker
Minneapolis-Honeywell
Rheem Electronics
S'west'n Ind. Electron.
Standard Electric Time
Taylor Instrument
Technical Oil Tool
Weston Electrical
Westronics

Temperature Controllers
Fenwal
West Instrument

Temperature Gages, Recorders
Allegany Instrument
Am. Machine & Metals
Bristol
A. W. Cash
Dale Co.
Fischer & Porter
Foxboro
General Controls
General Electric
Leeds & Northrup
Manning, Maxwell & Moore
Mason-Neilan
Minneapolis-Honeywell
Palmer Thermometers
Penn Instruments
Robertshaw-Fulton
Rochester Mfg.
Servo Corp.
Shand & Jurs
Statham Development
Taylor Instrument
Trinity Equipment
Vapor Recovery Systems
Weksler Thermometers
West Instrument
Weston Electrical
Westronics
Wheelco Instruments

Torque Gages, Recorders
Baldwin-Lima-Hamilton
Martin-Decker
Minneapolis-Honeywell
Westronics

Valve Controls
ELECTRONIC
Askania Regulator
Automatic Switch
Bendix, Pacific Div.
Conoflow
Cutler-Hammer
Fischer & Porter
Garrett Oil Tools
Jordan
Manning, Maxwell & Moore
Norwood Controls
Rockwell Mfg.
Shand & Jurs
S'west'n. Ind. Electron.
Statham Development

PNEUMATIC
Automatic Switch
Bettis
Black, Sivalls & Bryson
Cameron Iron Works
Conoflow
Farris Engineering
Fischer & Porter
Fisher Governor
Foxboro
Garrett Oil Tools
Guiberson
Gulf Coast
Leslie
Magnetrol
Marsh Instrument
Minneapolis-Honeywell
Powers Regulator
Republic Flow Meters
Research Controls
Rockwell Mfg.
Westinghouse Air Brake

Weight Indicators
Allegany Instrument
Baldwin-Lima-Hamilton
Cameron Iron Works
Line Scale
Martin-Decker
Minneapolis-Honeywell
Taylor Instrument
Westronics

Well Logging
Baroid, National Lead
Eastman Oil Well Survey
Halliburton
Industrial Instruments
McCullough Tool
Minneapolis-Honeywell
Petroleum Instrument
Phillips Electronics
Ruska Instruments
Ultra-Violet Products
Universal Atomics
Well Instrument Dev.
Westronics

Well Directional Survey
Sperry-Sun
Technical Oil Tool

Well Measurement Controllers
Halliburton

Instruments and Control Equipment Used in REFINING and PROCESSING

Analytical Controls
Consolidated Elec'dynam.
Fischer & Porter
Foxboro
Hallikainen Instruments
Leeds & Northrup
Mine Safety Appliance
Minneapolis-Honeywell
Tracerlab

Boiler Controls
Askania Regulator
Bailey Meter
Black, Sivalls & Bryson
A. W. Cash
Fischer & Porter
Foxboro
General Controls
Hays
Leeds & Northrup
Magnetrol
Mercoid
Minneapolis-Honeywell
Republic Flow Meters
Research Controls
Taylor Instrument
Watts Regulator

Boiler Indicators
ELECTRIC
General Controls
Hays
Leeds & Northrup
Minneapolis-Honeywell
Penn Instruments
Republic Flow Meters
Westronics

MECHANICAL
Bailey Meter
Barton Instrument
Black, Sivalls & Bryson
General Controls
Hays
Jerguson Gage & Valve
Meriam Instrument
Minneapolis-Honeywell
Yarnall-Waring

PNEUMATIC
Bailey Meter
Barton Instrument
Black, Sivalls & Bryson
Foxboro
General Controls
Hammel-Dahl
Hays
Leeds & Northrup
Minneapolis-Honeywell

Chemical Feed Control
American Instrument
Black, Sivalls & Bryson
Fischer & Porter
Jordan
Milton Roy
Minneapolis-Honeywell
Perkin-Elmer
Research Controls
Wallace & Tiernan

Coke Level Indicators
Baldwin-Lima-Hamilton
Robertshaw-Fulton
Tracerlab

Conductivity—Indicators, Recorders, Controllers
Bailey Meter
Bristol
Foxboro
General Electric
Industrial Instruments
Leeds & Northrup
Minneapolis Honeywell
Robertshaw-Fulton
Wheelco Instruments

Controllers & Regulators
ELECTRONIC
American Instrument
Automatic Switch
BJ Electronics
Bristol
Consolidated Elec'dynam.
Cutler-Hammer
Daytronics
Fenwal
Fischer & Porter
Fisher Governor
Foster Engineering
General Controls
General Electric
Hays
Hewlett Packard
Leeds & Northrup
Magnetrol
Manning, Maxwell & Moore
Minneapolis-Honeywell
Peschel Electronics
Reliance Electric & Eng.
Rheem Electronics
Robertshaw-Fulton
S'west'n. Ind. Electron.
Statham
Swartwout
Weston
Westronics
Wheelco

MECHANICAL
American Meter
Automatic Switch
Bailey Meter
Barton Instrument
B-I-F Industries
Black, Sivalls & Bryson
A. W. Cash
Fenwal
Fischer & Porter
Foster Engineering
General Controls
Mason-Neilan
Mercoid
Minneapolis-Honeywell
Taylor Instrument
Weston

HYDRAULIC
Askania Regulator
Barksdale Valves
Bettis
Black, Sivalls & Bryson
A. W. Cash
Fischer & Porter
Fisher Governor
Foster Engineering
Gadco Products
General Controls
Hammel-Dahl
Kobe
Leslie
Mason-Neilan

PNEUMATIC
Am. Machine & Metals
American Meter
Bailey Meter
Barksdale Valves
Barton Instrument
Bettis
B-I-F Industries
Black, Sivalls & Bryson
Bristol
A. W. Cash
Conoflow
Fischer & Porter
Fisher Governor
Foster Engineering
Foxboro
General Controls
Hammel-Dahl
Leeds & Northrup
Leslie
Magnetrol
Mason-Neilan
Merla Tool
Minneapolis-Honeywell
Powers Regulator
Republic Flow Meters
Research Controls
Taylor Instrument
Westinghouse Air Brake
Weston

Data Logging
Bendix, Pacific Div.
Shand & Jurs

Electric Power Controls
Am. Kloeckner-Moeller
Automatic Switch
Cutler-Hammer
ESCO
General Electric
Peschel Electronics

Flow Meters
DRY TYPE
American Meter
Bailey Meter
Barton Instrument
Bristol
Foxboro
Hays
Minneapolis-Honeywell
Penn Instruments
S'west'n. Ind. Electron.
Taylor Instruments

FULL BORE
Fischer & Porter
Foster Engineering
Schutte-Koerting

ORIFICE
American Meter
Bailey Meter
Barton Instrument
B-I-F Industries
Bristol
Fischer & Porter
Foxboro
Hays
Mason-Neilan
Meriam Instrument
Minneapolis-Honeywell
Penn Instruments
Republic Flow Meters
Robinson Orifice Fitting
Robinson Orifice, Tex.
Rockwell Mfg.
Rockwell Register
S'west'n. Ind. Electron.
Taylor Instrument

PITOT TUBE
Barton Instrument
Bristol
Foxboro
Meriam Instrument
Minneapolis-Honeywell

REMOTE INDICATION, INTEGRATION
Bailey Meter
Barton Instrument
Bendix, Pacific Div.
B-I-F Industries
BJ Electronics
Bristol
Brooks Rotameter
Fischer & Porter
Foxboro
Hammarlund
Hays
Jordan
Librascope
Mason-Neilan
Minneapolis-Honeywell
Panellit
Penn Instruments
Republic Flow Meters
Robertshaw-Fulton
Rockwell Register
S'west'n. Ind. Electron.
Taylor Instrument

VENTURI
Bailey Meter
Barton Instrument
B-I-F Industries
Fischer & Porter
Foxboro
Hays
Minneapolis-Honeywell
Penn Instruments

Flow Recorders
ELECTRICAL
Bailey Meter
B-I-F Industries
Bristol
Fischer & Porter
Foxboro
Hammarlund
Hays
Leeds & Northrup
Manning, Maxwell & Moore
Minneapolis-Honeywell
Penn Instruments
Republic Flow Meters
Schutte & Koerting
S'west'n. Ind. Electron.
Swartwout
Tracerlab
Westronics

MECHANICAL
American Meter
Bailey Meter
Barton Instrument
B-I-F Industries
Bristol
Fischer & Porter
Foxboro
Mason-Neilan
Minneapolis Honeywell
Penn Instruments
Schutte & Koerting
Taylor Instrument

Gas Indicators & Analyzers
Bailey Meter
Beckman Instruments
Consolidated Elec'dynam.
Fischer & Porter
Hallikainen
Hays
Leeds & Northrup
Mine Safety Appliances
Minneapolis-Honeywell
Perkin-Elmer
Permutit
Philips Electronics
S'west'n. Ind. Electron.

Liquid Level Gages
ELECTRONIC
Baldwin-Lima-Hamilton
Bendix, Pacific Div.
B-I-F Industries
BJ Electronics
Bristol
Fischer & Porter
Fisher Governor
Hays
Manning, Maxwell & Moore
Minneapolis-Honeywell
Penn Instruments
Robertshaw-Fulton
Shand & Jurs
Vapor Recovery Systems
Victory Engineering
Westronics

MECHANICAL
Bailey Meter
Barton Instrument
Bendix, Pacific Div.
B-I-F Industries
Bristol
Crosby-Ashton
Fischer & Porter
Foxboro
Jerguson Gage & Valve

Manning, Maxwell & Moore
Minneapolis-Honeywell
Norwood Controls
Penn Instruments
Rochester Mfg.
Shand & Jurs
Vapor Recovery Systems
Wallace & Tiernan
Yarnall-Waring

PNEUMATIC

Bailey Meter
Barton Instrument
B-I-F Industries
Bristol
Brooks Rotameter
Crosby-Ashton
Fischer & Porter
Fisher Governor
Foxboro
Meriam Instrument
Minneapolis-Honeywell
Republic Flow Meters
Vapor Recovery Systems
Wallace & Tiernan

pH Meters

Bailey Meter
Beckman Instruments
Bristol
Fish-Schurman
Foxboro
Leeds & Northrup
Minneapolis-Honeywell
Philips Electronics
Photovolt
Research Controls
Scientific Glass

Pressure

GAGES

Am. Machine & Metals
American Meter
Bailey Meter
Baldwin-Lima-Hamilton
BJ Electronics
Bristol
Consolidated Elec'dynam.
Crosby-Ashton
Fischer & Porter
Foxboro
General Controls
General Electric
Hays
Helicoid Gage Div.
J. E. Lonergan
Manning, Maxwell & Moore
Marsh Instrument
Martin-Decker
Minneapolis-Honeywell
Norwood Controls
Rochester Mfg.
Servonic Instruments
Taylor Instrument
Wallace & Tiernan
Weksler Thermometer

MECHANICAL RECORDERS

Allegany Instrument
Am. Machine & Metals
American Meter
Bailey Meter
Barton Instrument
B-I-F Industries
Bristol
Consolidated Elec'dynam.
Crosby-Ashton
Fischer & Porter
Foxboro
General Controls
Hammel-Dahl
Hays
Manning, Maxwell & Moore
Martin-Decker
Mason-Neilan
Minneapolis-Honeywell
Penn Instruments
Robertshaw-Fulton
Taylor Instrument
Weksler Thermometer
Weston

REMOTE READING RECORDERS

Bailey Meter
Barton Instrument
Bendix, Pacific Div.
B-I-F Industries
Bristol
Consolidated Elec'dynam.
Fischer & Porter
Foxboro
Hays
Leeds & Northrup
Librascope
Martin-Decker
Minneapolis-Honeywell
Penn Instruments
Republic Flow Meters
Shand & Jurs
Statham
Weksler Thermometer
Weston

SWITCHES

Barksdale Valves
Barton Instrument
Cutler-Hammer
Minneapolis-Honeywell
Servonic Instruments

Program-Process Controls

Am. Machine & Metals
Bailey Meter
Bendix, Pacific Div.
B-I-F Industries
BJ Electronics
Black, Sivalls & Bryson
Bristol
Consolidated Elec'dynam.
Eagle Signal
FPSCO
Fischer & Porter
Foxboro
General Electric
Jordan
Leeds & Northrup
Mason-Neilan
Minneapolis-Honeywell
Panellit
S'west'n Ind. Electron.
Statham
Taylor Instrument
Wheelco

Relief Valves

Crosby-Ashton

Shut-Down Valve

Automatic Switch
Research Controls

Stream Blenders

B-I-F Industries
Black, Sivalls & Bryson
Jordan
Minneapolis-Honeywell

System Control Panels

Automatic Switch
Bailey Meter
B-I-F Industries
Bristol
Cutler-Hammer
Foxboro
Fischer & Porter
Foxboro
General Electric
Leeds & Northrup
Minneapolis-Honeywell
S'west'n Ind. Electron.
Wheelco

Tachometers

Associated Research
Bailey Meter
Bristol
Louis C. Eitzen
Foxboro
General Electric
Hewlett-Packard
Martin-Decker
Minneapolis-Honeywell
Robertshaw-Fulton
S'west'n Ind. Electron.
Standard Electric Time
Technical Oil Tool
Weston
Westronics

Telemetering

Bailey Meter
Bendix, Pacific Div.
B-I-F Industries
BJ Electronics
Bristol
Consolidated Elec'dynam.
EPSCO
Fischer & Porter
Foxboro
General Electric
Hammarlund
Librascope
Martin-Decker
Minneapolis-Honeywell
Penn Instruments
Republic Flow Meters
Rheem Electronics
Servo
Shand & Jurs
S'west'n Ind. Electron.
Stromberg-Carlson
Vapor Recovery Systems
Veeder-Root
Victory Engineering
Warren Mfg.
Westronics

Temperature Gages

Allegany Instrument
Am. Machine & Metals
Bailey Meter
Bristol
Elec. Auto-Lite
Fischer & Porter
Foxboro
General Controls
Manning, Maxwell & Moore
Marsh Instrument
Mason-Neilan
Minneapolis-Honeywell
Palmer Thermometers
Rochester Mfg.
Servo
Shand & Jurs
Statham
Taylor Instrument
Trinity Equipment
Vapor Recovery Systems
Weksler
West Instrument
Westronics

Temperature Recorders

Bailey Meter
B-I-F Industries
Bristol
A. W. Cash
Fenwal
Fischer & Porter
Foxboro
General Electric
Hays
Leeds & Northrup
Manning, Maxwell & Moore
Minneapolis-Honeywell
Palmer Thermometers
Penn Instruments
Powers Regulator
Robertshaw-Fulton
Shand & Jurs
Swartwout
Weksler
West Instrument
Weston
Westronics
Wheelco

Valve Controls

ELECTRONIC

Askania Regulator
Automatic Switch
B-I-F Industries
Conoflow
Cutler-Hammer
Daytronic
Fischer & Porter
Jordan
Magnetrol
Manning, Maxwell & Moore
Norwood Controls
Rockwell Mfg.
Shand & Jurs
S'west'n Ind. Electron.
Statham
Swartwout
Vapor Recovery Systems
Westronics

PNEUMATIC

American Instrument
Bailey Meter
Bettis
Black, Sivalls & Bryson
Cameron Iron Works
A. W. Cash
Conoflow
Farris Engineering
Fischer & Porter
Foxboro
Leslie
Marsh Instrument
Magnetrol
Minneapolis-Honeywell
Powers Regulator
Republic Flow Meters
Research Controls
Rockwell Mfg.
Swartwout
Vapor Recovery Systems
Westinghouse Air Brake

Instruments and Control Equipment Used in OIL and GAS PIPELINING

Transmission Systems Control

Automatic Switch
Bailey Meter
Barton Instrument
Bendix, Pacific Div.
B-I-F Industries
Black, Sivalls & Bryson
Bristol
Fischer & Porter
Foxboro
Hammarlund
Manning, Maxwell & Moore
Minneapolis-Honeywell
Raytheon Mfg.
Robertshaw-Fulton
Shand & Jurs
S'west'n Ind. Electron.
Stromberg-Carlson

Controllers & Regulators

ELECTRONIC

Automatic Switch
Baldwin-Lima-Hamilton
B-I-F Industries
BJ Electronics
Bristol
Cutler-Hammer
Daytronic
Fischer & Porter
Fisher Governor
Foster Engineering
General Controls
General Electric
Hewlett-Packard
Jordan
Leeds & Northrup
Manning, Maxwell & Moore
Minneapolis-Honeywell
Peschel Electronics
Reliance Elec. & Eng.
Rheem Electronics
Robertshaw-Fulton
S'west'n Ind. Electron.
Statham
Superior Electric
Swartwout
Weston
Westronics

HYDRAULIC

Askania Regulator
Barksdale Valves
Bettis
Black, Sivalls & Bryson
Bristol
A. W. Cash
Farris Engineering
Fischer & Porter
Fisher Governor
Foster Engineering
Gadco Products
General Controls
Hammel-Dahl
Kobe
Leslie
Mason-Neilan

MECHANICAL

American Meter
Automatic Switch
Bailey Meter
Barton Instrument
B-I-F Industries
Black, Sivalls & Bryson
Bristol
A. W. Cash
Fischer & Porter
Foster Engineering
General Controls
Mason-Neilan
Mercoid
Minneapolis-Honeywell
Taylor Instrument
Weston

PNEUMATIC

Am. Machine & Metals
American Meter
Bailey Meter
Barksdale Valves
Barton Instrument
Bettis
B-I-F Industries
Black, Sivalls & Bryson
Bristol
A. W. Cash
Conoflow
Fischer & Porter
Fisher Governor
Foster Engineering
Foxboro
General Controls
Hammel-Dahl
Leeds & Northrup
Leslie
Magnetrol
Mason-Neilan
Minneapolis-Honeywell
Powers Regulator
Republic Flow Meters
Research Controls
Robertshaw-Fulton
Taylor Instrument
Vapor Recovery Systems
Watts Regulator
Westinghouse Air Brake
Weston

Corrosion Testers

Labline

Data Logging

Bendix, Pacific Div.
Shand & Jurs

Electric Power Controls

Am. Kloeckner-Moeller
Automatic Switch
Cutler-Hammer
ESCO
General Electric
Norwood Controls
Peschel Electronics

Flow Meters

DRY TYPE

American Meter
Bailey Meter
Barton Instrument
Bristol
Foxboro
Minneapolis-Honeywell
Penn Instruments
S'west'n Ind. Electron.
Taylor Instrument

FULL BORE

Fischer & Porter
Foster Engineering

ORIFICE

American Meter
Bailey Meter
Barton Instrument
B-I-F Industries
Bristol
Fischer & Porter
Foxboro
Mason-Neilan
Meriam Instrument
Minneapolis-Honeywell
Penn Instruments
Republic Flow Meters
Robinson Orifice Fitting
Robinson Orifice of Tex.
Rockwell Mfg.
Rockwell Register
S'west'n Ind. Electron.
Taylor Instrument

PITOT TUBE

Barton Instrument
Foxboro
Meriam Instrument
Minneapolis-Honeywell
Taylor Instrument

REMOTE INDICATION, INTEGRATION
American Meter
Bailey Meter
Barton Instrument
Bendix, Pacific Div.
B-I-F Industries
BJ Electronics
Bristol
Brooks Rotameter
Fischer & Porter
Foxboro
Jordan
Leeds & Northrup
Librascope
Mason-Neilan
Minneapolis-Honeywell
Norwood Controls
Penn Instruments
Republic Flow Meters
Rockwell Register
S'west'n Ind. Electron.
Taylor Instrument

VENTURI
Bailey Meter
Barton Instrument
B-I-F Industries
Fischer & Porter
Foxboro
Minneapolis-Honeywell
Penn Instruments
Taylor Instrument

Liquid Level Gages

ELECTRONIC
Baldwin-Lima-Hamilton
Bendix, Pacific Div.
B-I-F Industries
BJ Electronics
Fischer & Porter
Fisher Governor
Manning, Maxwell & Moore
Minneapolis-Honeywell
Penn Instruments
Robertshaw-Fulton
Shand & Jurs
Vapor Recovery Systems
Victory Engineering
Westronics

MECHANICAL
Bailey Meter
Barton Instrument
Bendix, Pacific Div.
Crosby-Ashton
Fischer & Porter
Foxboro
Jerguson Gage & Valve
Librascope
Manning, Maxwell & Moore
Minneapolis-Honeywell
Penn Instruments
Shand & Jurs
Vapor Recovery Systems
Wallace & Tiernan

PNEUMATIC
Bailey Meter
Barton Instrument
B-I-F Industries
Bristol
Brooks Rotameter
Crosby-Ashton
Fischer & Porter
Fisher Governor
Foxboro
Meriam Instrument
Minneapolis-Honeywell
Republic Flow Meters
Rochester Mfg.
Vapor Recovery Systems
Wallace & Tiernan

Gas Indicators & Analyzers

Bailey Meter
Barton Instrument
Beckman Instruments
Central Scientific
Consolidated Elec'dynam.
Fischer & Porter
Hallikainen Instruments
Leeds & Northrup
Mine Safety Appliances
Minneapolis-Honeywell
Permutit
Petroleum Instrument
S'west'n Ind. Electron.

Soil Resistivity Surveying Instruments

Associated Research
Ercona
Minneapolis-Honeywell
Westronics

Pressure

GAGES
Am. Machine & Metals
American Meter
Bailey Meter
BJ Electronics
Cameron Iron Works
Consolidated Elec'dynam.
Fischer & Porter
Foxboro
General Controls
General Electric
Helicoid Gage Div.
J. E. Lonergan
Marsh Instrument
Martin-Decker
Minneapolis Honeywell
Norwood Controls
Servonic Instruments
Statham
Taylor Instrument
Wallace & Tiernan
Weksler Thermometer

MECHANICAL RECORDERS
Allegany Instrument
Am. Machine & Metals
American Meter
Bailey Meter
Barton Instrument
Consolidated Elec'dynam.
Crosby-Ashton
Electric Auto-Lite
Fischer & Porter
Foxboro
General Controls
Hammel-Dahl
Manning, Maxwell & Moore
Martin-Decker
Mason-Neilan
Minneapolis-Honeywell
Penn Instruments
Rochester Mfg.
Taylor Instrument
Weksler Thermometer
Weston

REMOTE READING RECORDERS
Am. Machine & Metals
American Meter
Bailey Meter
Baldwin-Lima-Hamilton
Barton Instrument
Bendix, Pacific Div.
Bristol
Consolidated Elec'dynam.
Fischer & Porter
Foxboro
General Electric
Leeds & Northrup
Librascope
Manning, Maxwell & Moore
Marsh Instrument
Martin-Decker
Mason-Neilan
Minneapolis-Honeywell
Panellit
Penn Instruments
Reliance Elec. & Eng.
Republic Flow Meters
Robertshaw-Fulton
Servo Corp.
Shand & Jurs
Swartwout
Taylor Instrument
Weksler Thermometer
Weston
Westronics

SWITCHES
Barksdale Valves
Barton Instrument
Cutler-Hammer
Minneapolis-Honeywell
Servonic Instruments

Tachometers

Associated Research
Bailey Meter
Bristol
Louis C. Eitzen
Foxboro
General Electric
Hewlett-Packard
Martin-Decker
Minneapolis-Honeywell
Rheem Electronics
S'west'n Ind. Electron.
Taylor Instrument
Technical Oil Tool
Weston
Westronics

Telemetering

Bailey Meter
Bendix, Pacific Div.
B-I-F Industries
BJ Electronics
Bristol
Consolidated Elec-dynam.
EPSCO
Fischer & Porter
Foxboro
General Electric
Hammarlund Mfg.
Martin-Decker
Minneapolis-Honeywell
Penn Instruments
Raytheon Mfg.
Republic Flow Meters
Rheem Electronics
Servo
Shand & Jurs
S'west'n Ind. Electron.
Stromberg-Carlson
Vapor Recovery Systems
Victory Engineering
Warren Mfg.
Westronics

Temperature Gages

Allegany Instrument
Am. Machine & Metals
Bailey Meter
B-I-F Industries
Bristol
Electric Auto-Lite
Fischer & Porter
Foxboro
General Controls
General Electric
Manning, Maxwell & Moore
Marsh Instrument
Mason-Neilan
Minneapolis-Honeywell
Palmer Thermometers
Rochester Mfg.
Servo
Shand & Jurs
Statham
Taylor Instrument
Trinity Equipment
Weksler Thermometer
West Instrument
Weston
Westronics

Temperature Recorders

Bailey Meter
B-I-F Industries
Bristol
A. W. Cash
Electric Auto-Lite
Fischer & Porter
Foxboro
General Electric
Leeds & Northrup
Manning, Maxwell & Moore
Minneapolis-Honeywell
Palmer Thermometers
Penn Instruments
Powers Regulator
Robertshaw-Fulton
Shand & Jurs
Swartwout
Vapor Recovery Systems
Weksler Thermometer
West Instrument
Weston
Westronics
Wheelco

Valve Controls

ELECTRONIC
Aaknis Regulator
Automatic Switch
A. W. Cash
Cutler-Hammer
Daytronic
Fischer & Porter
Jordan
Manning, Maxwell & Moore
Norwood Controls
Rockwell Mfg.
Shand & Jurs
S'west'n Ind. Electron.
Statham
Swartwout
Vapor Recovery Systems
Westronics

HYDRAULIC
B-I-F Industries

PNEUMATIC
Automatic Switch
Bailey Meter
Bettis
Black, Sivalls & Bryson
Bristol
Cameron Iron Works
A. W. Cash
Farris Engineering
Fischer & Porter
Foxboro
Leslie
Marsh Instrument
Minneapolis-Honeywell
Powers Regulator
Republic Flow Meters
Research Controls
Rockwell Mfg.
Swartwout
Vapor Recovery Systems
Weston

Instruments and Control Equipment in PETROLEUM LABORATORIES

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Consolidated Elec'dynam.
Fisher Scientific
Hallikainen Instruments
Perkin-Elmer
S'west'n Ind. Electron.

COLORIMETERS
Barton Instruments
Ercona
Fish-Schurman
Fisher Scientific
Gardner Laboratory
Hallikainen Instruments
Labline
Photovolt
Scientific Glass

REFRACTOMETERS
Consolidated Elec'dynam.
Ercona
Fish-Schurman
Fisher Scientific
Scientific Glass

SPECTROMETERS
Beckman Instruments
BJ Electronics
Consolidated Elec'dynam.
Ercona
Fish-Schurman
Fisher Scientific
Leeds & Northrup
Perkin-Elmer
Scientific Glass

TITRATION
American Instrument
Beckman Instruments
Consolidated Elec'dynam.
Fisher Scientific
Laboratory Equipment
Robertshaw Fulton
Scientific Glass
Testing Machines

X-RAY
Philips Electronics

Calibration Instruments

Consolidated Elec'dynam.
Crosby-Ashton
Fisher Scientific
Halliburton
Hallikainen Instruments
Kin Tel
Leeds & Northrup
Martin-Decker
Midwestern Instruments
Minneapolis-Honeywell
Norwood Controls
Ruska Instrument
Schutte & Koerting
Statham
Wallace & Tiernan

Chambers, Temperature

Statham
Tenney Eng.

Computers

ElectroData
Librascope
Ramo-Wooldridge
S'west'n Ind. Electron.
Standard Electric Time

Core Analysis

Mine Safety Appliance
Minneapolis-Honeywell
Perkin-Elmer
Ruska Instrument

Distillation

Labline

Electronic Measurement

Baldwin-Lima-Hamilton
Consolidated Elec'dynam.
Daytronic
Delsen
Fischer & Porter
Fisher Scientific
Kin Tel
Leeds & Northrup
Midwestern Instruments
Minneapolis-Honeywell
Peschel Electronics
Scientific Indus. Electron.
Statham
Weston
Westronics
Wheelco

Electron Microscopes

Philips Electronics

Nuclear Research

Nuclear Development

Oil Tests

Lewis C. Eitzen

pH Meters

Beckman Instruments
Fish-Schurman
Fisher Scientific
Leeds & Northrup
Minneapolis-Honeywell
Philips Electronics
Photovolt
Scientific Glass
Testing Machines

Radiological Measurement

BJ Electronics
Fisher Scientific
Hallikainen Instruments
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Sample Bombs

BJ Electronics
Daniel Orifice
Labline
Martin-Decker
Ruska Instrument
Scientific Glass
Vapor Recovery Systems

Strain Measuring Devices

Baldwin-Lima-Hamilton
Consolidated Elec'dynam.
Daytronic
Martin-Decker
Midwestern Instruments
Minneapolis-Honeywell
Sanborn
Statham
Westronics

Thermometers & Hydrometers

Fischer & Porter
Fish-Schurman
Fisher Scientific
Manning, Maxwell & Moore
Marsh Instrument
Minneapolis-Honeywell
Palmer Thermometers
Refinery Supply
Rochester Mfg.
Scientific Glass
Statham
Weksler Thermometer
Weston
Wheelco

Timers

General Electric
Hallikainen Instruments
Labline
Merla Tool
Scientific Glass
Standard Electric Time
Statham

Vapor Pressure

Consolidated Elec'dynam.
Hallikainen Instruments
Labline
Minneapolis-Honeywell
Refinery Supply
Scientific Glass

Viscometers

Louis C. Eitzen
Fischer & Porter
Fish-Schurman
Fisher Scientific
Gardner Laboratory
General Electric
Hallikainen Instruments
Labline
Ruska Instrument
Scientific Glass
Testing Machines
Visco-Meter

sixth of a series

These men have exchanged the familiar shelter of the executive suite for the rough and tumble atmosphere of the classroom where shirt sleeves are the accepted attire and a man's ability to formulate and express his ideas his only claim to status.

Commencement Day for Executives

At Northwestern's Institute for Management, 37 executives are graduated after each of three four-week courses

Ruth A. Driscoll

SINCE 1951, 473 men from 158 companies have completed four weeks of intensive training in the Institute for Management on Northwestern University's lakefront Chicago campus. Most of the men are employed in private industry in large, medium, and small companies, although some are engaged in government and educational work.

The median age of the men nominated by their companies for enrollment in the Institute is 45 years; no one under 35 years of age is accepted. More important than the man's age is his capacity to learn. Many of the men have reached the top in the particular area in which they have concentrated during their careers and they are considered to be in need of re-orientation from the specialized approach to a generalized view of their companies' problems. Moreover, they have an opportunity in the Institute to share in experiences with other men equally well equipped in a joint attempt to bring their thinking processes abreast of the changing concept of the part industry must play in the community and the world at large.

Case studies form the basis of the Institute course of study. These cases are the tangible result of research into real problems faced by actual companies. The men are expected to spend eight hours a day preparing for assignments, for the most part reading and analyzing cases. Two classes are held, one in "Top Management Policy and Administration" and the other in "Managerial Responsibilities and Their Limits." Because of the heavy schedule starting daily at 8:30 a.m. and often ending with a dinner meeting addressed by a guest speaker, the participants are required to live on the campus and to be freed from all company responsibilities.

In selecting participants from the many highly qualified applicants, the Committee on Selection is governed by its desire to create a balanced group but one which is diversified. For the greatest benefit of the individual members, the groups represent widely differing types of companies, various geographical locations including foreign countries, companies with peculiar problems as well as companies with typical problems, large and small companies.

Instructors in the Institute include Richard Donham, dean of the School of Business, who established the executive development program at Northwestern, and Leon A. Bosch, associate dean of the School and current director of the Institute. Other faculty members in the Graduate School of Business Administration complete the roster of Institute faculty. Speakers at special meetings have been corporate leaders, government officials, union executives, and university scholars.

Dates of the 1957 sessions are: Fourteenth Session, June 23 to July 19; Fifteenth Session, July 21 to August 16; Sixteenth Session, August 18 to September 13.

The fee of $1000 per man covers tuition, room, books, and supplies. Each participant pays the cost of his own meals, laundry, and personal expenses. Requests for further information may be addressed to Leon A. Bosch, Associate Dean, Graduate School of Business Administration, Northwestern University, Wieboldt Hall, Chicago 11, Illinois.

The reaction of the men to this new look at themselves was aptly expressed in the classbook published by the class of 1955 Eighth Session: "From the rigidities of habit and limited outlook we salvaged a measure of resiliency. This demanded, of course, some prodding — gently yet firmly applied. We noted problems and searched for answers and found stimulation in varied reactions of many minds." ★ ★ ★

Miss Driscoll is Administrative Assistant, Northwestern University School of Business, 339 East Chicago Avenue, Chicago 11, Illinois.

Deep in the Earth There's Another Reason Layne's on Top!

THE LAYNE IMPELLER is that reason, because a pump can be no better than its impeller.

There are two main considerations in impeller evaluation—QUALITY AND PERFORMANCE.

QUALITY—The materials used in the manufacture of a Layne impeller must be tough, durable and possess excellent *surface quality* and they must be able to insure *dimensional accuracy*. Metal patterns are used in casting high quality phosphor gear bronze into Layne impellers. Other special metals are specificed when necessary.

PERFORMANCE—A Layne impeller is correct in hydraulic design based on 75 years of Layne experience through thousands of successful installations and tests. Correct impeller design determines a pump's performance in any particular hydraulic condition.

Each Layne impeller is precision manufactured. Because no one technique is adequate, both hand finishing and special machining are used in balancing and tooling the impeller. Working to a rigid and minimum tolerance, specially designed gauges and instruments check each step to the finish of a Layne impeller . . . from water passages and angles to vane thickness.

Layne Impeller sizes range from 4" diameter and up, as specified.

The result — an impeller which operates deep in the recesses of the earth dynamically in balance. Each remaining component part of a Layne pump receives the same careful engineered attention, and when assembled assures complete pump perfection giving you years of trouble-free service.

Layne's 75 years of experience puts Layne on top!

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75 YEARS OF PROGRESS

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LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD

Dealing with unknowns is basically hazardous business. That's why at our Denver Research Center they take steps to see that . .

Safety's in on the Search

ONE night not long ago, Floyd Clews, janitor at our new Denver Research Center, was making his rounds of the building. He entered an empty laboratory and immediately detected an odor of natural gas. Investigation showed that gas was escaping from a line coming into the room.

The next day Floyd reported the incident and suggested that all lines to the laboratories be turned off each night.

Another time, Vilmer Porter observed that the light switches in the labs arced noticeably when they were flipped on. He suggested that the switches be changed to a non-arcing type, to eliminate a potential fire hazard.

Naturally, both of the suggestions were gratefully accepted and were immediately carried out. These are just two examples of how people at the Research Center think of their safety program as a community problem. Their goal is to have a group of employees who are all fully aware of the safety problems they must live with and who actively work to correct unsatisfactory safety conditions. Of course, this is not a new idea to The Ohio Oil Company. Production crews, refinerymen and others have been doing this same thing for years.

But in the case of the Center, they are dealing with a safety problem which is altogether new to the company. In research, scientists are constantly dealing with unknowns. And it is this inherent feature of research that makes the work basically hazardous. At times the scientists may be dealing with substances that are highly flammable, toxic or explosive. Some experiments may require high pressures or radiation. With this kind of situation, safety cannot be just something extra added to a job when time permits. Giant steps must be taken to make certain that safety is in on the search from the beginning.

And this is what is done. When our scientists devise new apparatus or set up experiments they take every precaution to make sure nothing will get out of hand. But safety comes into the picture even before that. The Research Center was designed from the beginning to be a safe place for all personnel to work.

Each laboratory, for example, is provided with an escape hatch, or second means of exit, into an adjacent laboratory in case the original exit is cut off. Inside each lab, near the exit to the corridor, is a safety shower, which, when a chain is pulled, will release 40

This is reprinted from The Beacon, Ohio Oil Company magazine, for June 1957, Eugene L. Price, editor.

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Latest surfactant mud materials

give fast, trouble-free drilling

DMS & DME drilling mud additives are one of the mud industry's biggest advances in decades: a "surfactant mud" system with unique in-the-hole advantages:

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2. **MOVES CUTTINGS OUT FASTER.** Lubricates cuttings and gets them away from the bit faster and out of the hole quicker.

3. **QUICKER SETTLING IN MUD PITS.** Drilled solids settle out faster, giving less solids build-up, easy mud control, less cost for weight materials.

4. **STABLE TO HIGH TEMPERATURES.** DMS & DME muds are stable at the highest temperatures ye encountered in drilling.

These new surfactant muds are easy to use, easy to control. They let you drill faster with less strain, and pull a clean bit from a clean hole. DMS & DME are distributed to the oil industry everywhere through Baroid Division, National Lead Company. Write direct to Baroid using convenient coupon below, for a complete 10-page technical bulletin on DMS & DME.

COMPOUND MUD WITH DMS & DME TO MEET YOUR SPECIAL NEEDS

Water-phase muds can be made easily with DMS additive and standard materials. For oil emulsion muds, add DME. Both are nonionic chemicals. Other principal mud additives generally used include a polyanionic filtration control agent and electrolyte such as calcium sulfate (for a calcium surfactant mud) or sodium chloride (for a sodium surfactant mud). Complete applications are described in DMS-DME bulletin from Baroid Division, National Lead Co.

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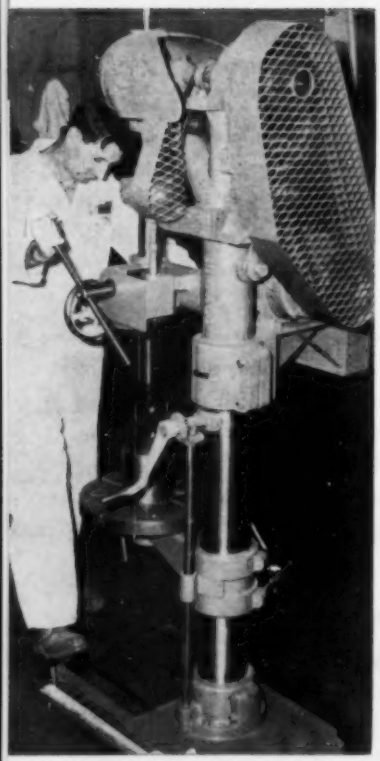
Safety's in on the Search

Because of large number of related pipes in mechanical equipment room, proper safety of operation requires knowledge of the systems and valves. Denver Whiteside shows how problem was simplified by marking pipes and conduits with system colors, names, and direction of flow.



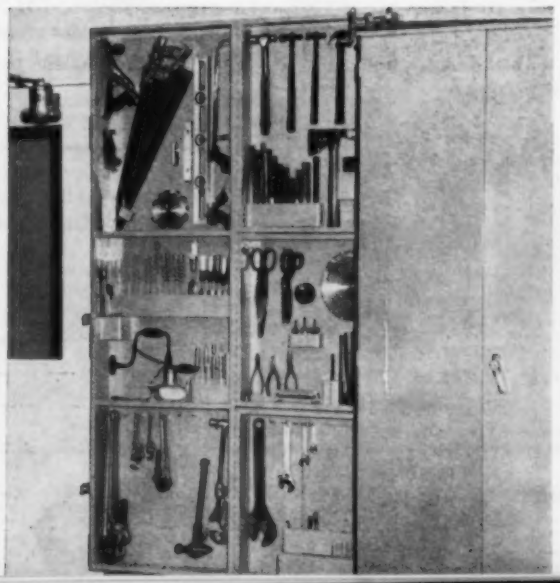
Safety is looked upon as a community problem at the Center. Arden Durfee, who is operating the machine, devised and built the belt guards on this drill press. Ed Gleason built the guard for the gears on the feed mechanism.

gal of water per min. Air above the laboratory ceilings is changed six times each hour to remove gases that might be escaping. Each room is equipped with a roll-around blanket for snuffing out fire, and each laboratory has a fire extinguisher to suit the type experiment being carried on.

Throughout the Center are other built-in safety features. And when the new unit was put into operation, one of the first things done was the naming of a safety committee. This committee has three members, two of whom rotate after six months' service. The third member is permanent. The committee consists of one scientist, one shop man and one other person. The present members are Don Darden, building and shop superintendent, who is head of the committee and the permanent member; Dr. William Ferguson, chemistry section, and Denver Whiteside, building engineer.

The committee is still in the process of developing its program. They are setting up schedules for safety meetings and presentations, such as movies, talks and posters, and are developing a safety code. From the start they realized that the best equipment is only as good as the people who use it. So they have stressed the fact that safety is the responsibility of the individual.

The idea caught on almost at once. Several employees have taken a very



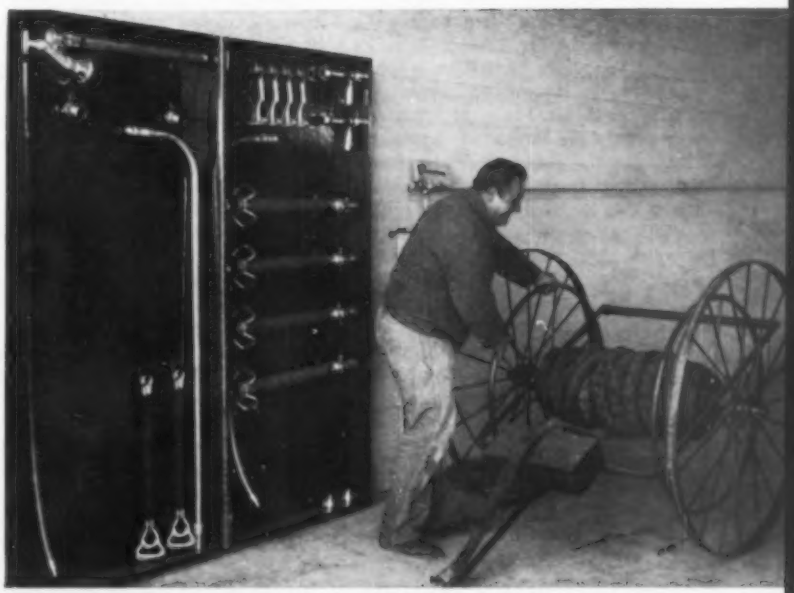
Workers at the Center have solved many safety problems by good housekeeping. Arden Durfee built this tool cabinet for maintenance shop.

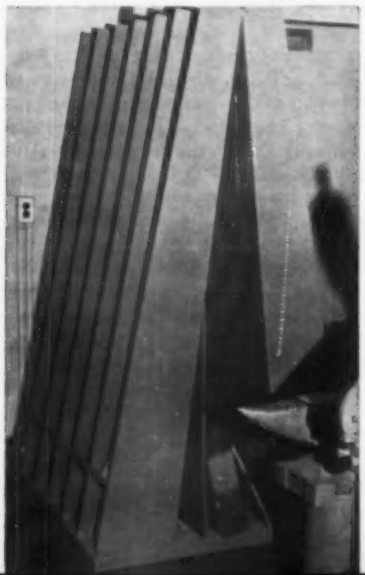
Other problems have been solved by good storage facilities for compressed gas cylinders.

Ed Gleason solved safety and housekeeping problems by making: (1) Splash shield; (2) trough to catch oil from lathe.

active part in the safety program. Arden Durfee, for instance, developed a compressed gas cylinder storage rack, designed so that the bottles tilt back slightly, and which has chains to prevent the bottles from falling out. The chains also act as static grounds. Ed Gleason, instrument man, designed a plastic, metallic-base splash shield for lathes to keep cutting oil from being sprayed on the floor. Others have made similar contributions.

And so the community approach is beginning to pay off at the Research Center. From the time the Center began operation, there have been very few accidents of any kind, and there have been no lost time accidents. ★ ★





Neat arrangement of fire-fighting equipment (above) makes it readily accessible and thus more efficient and safer. Proper storage of miscellaneous parts and equipment (left) also aids the safety program.

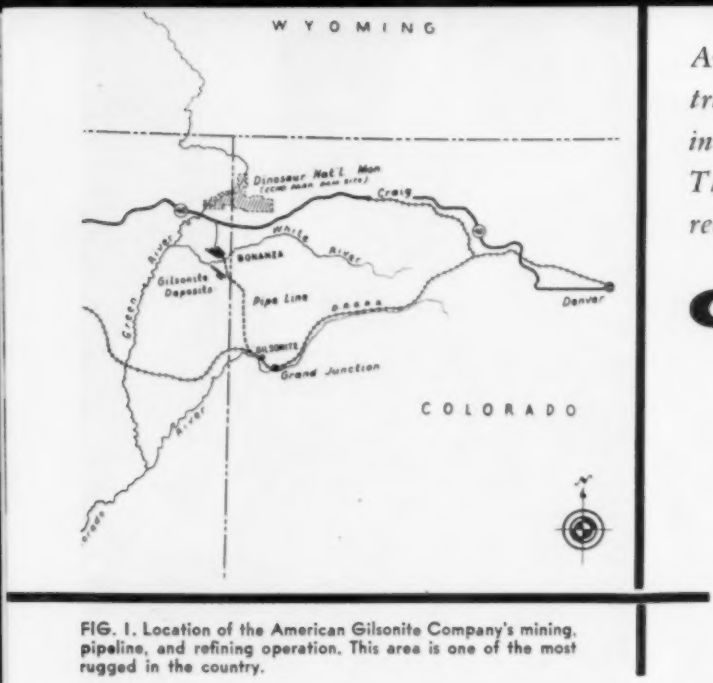


FIG. 1. Location of the American Gilsonite Company's mining, pipeline, and refining operation. This area is one of the most rugged in the country.

American Gilsonite Company mines, transports, and converts solid hydrocarbons into gasoline and metallurgical coke . . . The new refinery — first of its kind — recently went onstream.

Gasoline From Mineral Oil!

AMERICAN Gilsonite Company's bi-state mining, pipeline, and refinery operations were formally opened early in August by the Secretary of the Interior, Frederick A. Seaton. It was built at a cost of more than $16,000,000.

Although not an extremely large operation in today's oil industry, oilmen in all branches are watching the installation carefully. As Secretary Seaton stated, this is the first privately-financed commercial operation to produce high-octane gasoline from a solid hydrocarbon, Gilsonite* ore.

In a speech of welcome, Ernest F. Goodner, president of American Gilsonite, explained the historic significance of the occasion and the revolutionary aspects for the oil industry of the new operation. He said: "This refinery proves the economic feasibility of deriving petroleum products from other than conventional sources. We believe this is opening up unlimited possibilities for the vast quantities of petroleum like materials, now lying unusued, in which this area abounds."

A number of scientific and engineering "firsts" had to be recorded before operations could begin on a commercial basis, according to Goodner. In addition to "polishing" operation techniques, three achievements especially stand out, in his opinion.

1. "Wet" mining methods. Developed during the last four years and introduced at Bonanza, Utah, center of the company's mining operations since 1904, two new methods eliminate explosion hazards and reduce hand labor required in the actual mining operation.

2. Pipeline. A 6-in. pipeline carries 700 tons of ore a day over 72 miles of some of the most rugged, mountainous terrain in the country, from the Bonanza mines to the refinery at Gilsonite, Colorado, near Grand Junction. In the Book Cliff Mountains, at Baxter Pass, the $2,000,000 line reaches its maximum elevation of 8500 ft. It rises 2000 ft in one six-mile stretch, 3500 ft in the 40 miles between the pass and the Bonanza mines.

3. Refinery operations. The processing plant converts solid Gilsonite into 1300 bbl daily of high octane gasoline and 275 tons of high purity metallurgical coke. The gasoline is marketed in the Colorado area and the coke sold to aluminum producers and other specialty carbon users.

*Gilsonite is a registered trademark.

Geology and Economics

Gilsonite is a natural occurring solid hydrocarbon, having the scientific designation "Uintaite." The principal veins are located in the Uintah Basin of eastern Utah and western Colorado. Technically, it is an asphaltite, not an asphalt, having a high resin content and very little sulfur. It has a high softening point varying from 275 to 500 F. Estimated reserves of Gilsonite are 16 million tons—enough for more than 50 years.

Precise origins of Gilsonite are uncertain. The most accepted explanation is that it was formed from the partial decomposition of organic material in shale formations, much in the same way that oil is formed. However, massive upheavals of the shale squeezed this organic material upward into stress cracks formed in the overlying beds of sandstone. These today are the vertical fissures from which Gilsonite is mined.

Gilsonite fissures strike northwest-southeast through the Uintah Basin, varying in width from a few inches to 22 ft. The vertical extent of these veins has been mined to a depth of 1500 ft in the western end of the basin. The outcrop of one vein may be traced for more than nine miles, and some go down as deep as 2000 ft. All deposits in the basin are enclosed in an elliptical area about 10 by 60 miles.

Samuel H. Gilson, an energetic settler of the Old West, became interested in the mineral in 1884 and tried to find a market for it. His enthusiasm resulted in the name — Gilsonite — being applied to the product by the local people. The name "Gilsonite" is a registered trademark of Barber Asphalt Company, predecessor to American Gilsonite Company, which is jointly owned by Barber Oil Company and Standard Oil Company of California.

How Gilsonite is Mined

Radically different and improved methods of mining Gilsonite have been developed for supplying the type of ore required for refinery and coke processing plant and for other products.

Earliest method was to pick away at the ore, letting it roll down an incline, where it was loaded into buckets and hauled to the surface. Until a short time ago, most Gilsonite was mined by mechanical modifications of this method. Although it will not burn in a solid state, Gilsonite dust is highly explosive and this hazard is an ever-present one in old mining methods.

Two new "wet" mining methods have been developed. Both methods reduce the explosion hazard to practically

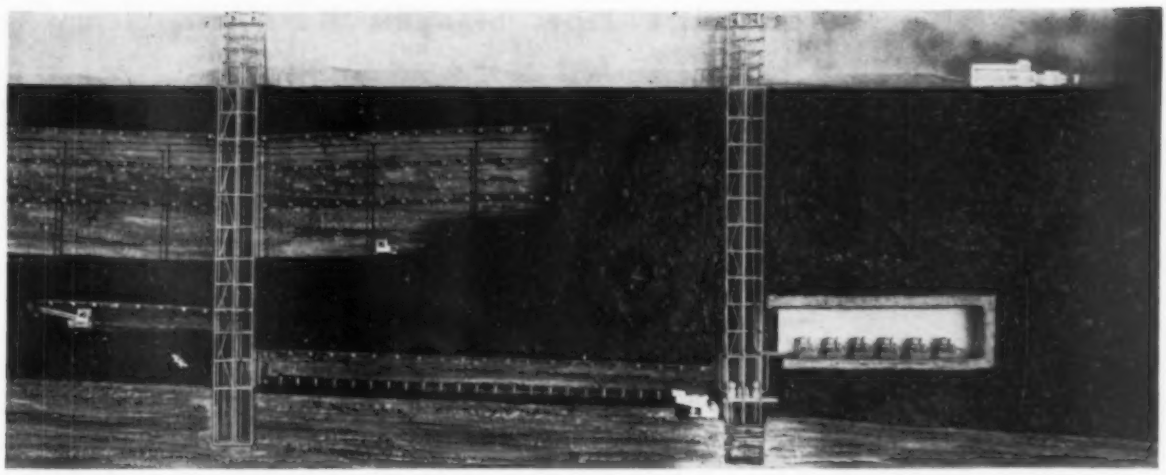


FIG. 2. Model of a Gilsonite vein illustrating the hydraulic mining methods developed by American Gilsonite. Jets of water or cutter teeth break up the ore, and it is washed down the drift to a sump. From that point it is either pumped in slurry form or dewatered and hoisted to the surface.

zero and reduce the need for hand labor in the actual mining operations.

First step is to sink a deep shaft into the Gilsonite vein. The vein must be at least six feet wide, and the shaft is initially sunk to more than 850 ft deep. Next, drifts or tunnels are dug from either side of the shaft by means of a jet cutting car, equipped with two different types of cutting heads, depending on the type of ore mined. Some types of Gilsonite ore contain tiny cracks or fractures. In these veins, a powerful jet of water, issuing from a ¼-in. nozzle, with a pressure of 2000 psi, is played on the surface of the ore. The stream of water penetrates the tiny fissures, the ore breaks apart and falls to the bottom of the drift. The drifts are cut on a rising grade of approximately 2½ deg so that it can be washed down the drift to the main shaft, down the shaft to a sump.

Large lumps of ore are crushed to minus ¾-in. before entering the sump. Water and minus ¾-in. ore are pumped from sump to surface with centrifugal pumps.

When a drift is completed, the cutting machine returns to the shaft, begins a new drift and repeats the entire operation. Every 50 ft of depth, a floor will be installed for overhead protection. The walls will be lined almost solidly with timber. About every 350 ft of depth, a pillar of ore approximately 30 ft thick will be left horizontally between the walls for major protection and strengthening.

Surface Handling at the Mines

Ore destined for the refinery is pumped to the surface, dewatered, crushed and then recombined in a tank with a portion of the water which carried it from the bottom of the mine. This slurry is prepared in a proper pumping proportion and then cleansed in a process that drops out the sand, rock and other tramp material.

After cleaning, the material is stored in 5000-bbl tanks. The tanks are agitated to keep the material suspended, and from these tanks slurry is pumped through the pipeline to the refinery.

Pipeline Operations

This 6-in. 72-mile pipeline transports 700 tons daily of ore from mines over two suspension bridges, across an 8500-ft mountain pass, and into the plant at Gilsonite, Colorado.

The entire pipeline is laid at a reasonably flat slope, except for two miles past the summit of Baxter Pass, the highest point, where 21 deg slopes were necessary. Initially, solids concentration of 35 percent Gilsonite-65 percent water are being sent through the line. Discharge rate is 350 gal per min.

Designed for continuous flow, the line will be shut down only after all the slurry is flushed from the system. Three electric-driven, 300 hp slurry pumps are at the Bonanza pump station; two are normally used and one is a spare. Discharge pressure is 2200 psi.

If power should fail, a diesel-driven pump will be cut into the line and flush the system with water. This pump usually provides high-pressure water for ore cutting in the mines. A final measure of protection is the 8500-ft-high reservoir at the summit of Baxter Pass. This reservoir can flush the system in both directions. There is also a high-pressure pump at the refinery that can back-flush the line.

Designing Pipeline

A great deal of research went into the pipeline design. A pilot model was built at Colorado School of Mines Research Foundation (Golden). A radioactive section of pipe was included in the test line. By measuring the radioactivity of the slurry in the effluent, it was possible to determine, with the highest accuracy, the corrosion and wear that was taking place within the test pipeline.

Pipeline tests were conducted at Golden in a 500-ft closed loop of full-size pipe. One of the major factors found in establishing the pipeline design was the particle size of the Gilsonite in the feed slurry at the mine end. Although the pumps could handle particles of a ¼-in. size, results were dramatically improved with an 8-mesh size.

This smaller particle size also decreases degradation, or breaking down of the particles as they travel through the pipeline. It also makes de-watering easier, and makes it easier to maintain a suspension through the line.

Refinery Operations

The American Gilsonite Company operation is the first privately-financed plant in the United States to manufacture conventional petroleum products from non-petroleum sources. The plant includes several unique processing features. It is the first coking plant to perform the complete coking operation at a single site, for American Gilsonite both *produces and calcines* the coke here. The plant, one of the larger delayed coking units in the country, makes 275 tons a day of a product of exceptional chemical purity and one with ready markets in metallurgical refining and in specialty carbon fields.

Before the Gilsonite can be fed to the delayed coking unit, it must be separated from pipeline water. Since Gilsonite is hydrophobic, it can be separated from the water by straightforward filtering operations.

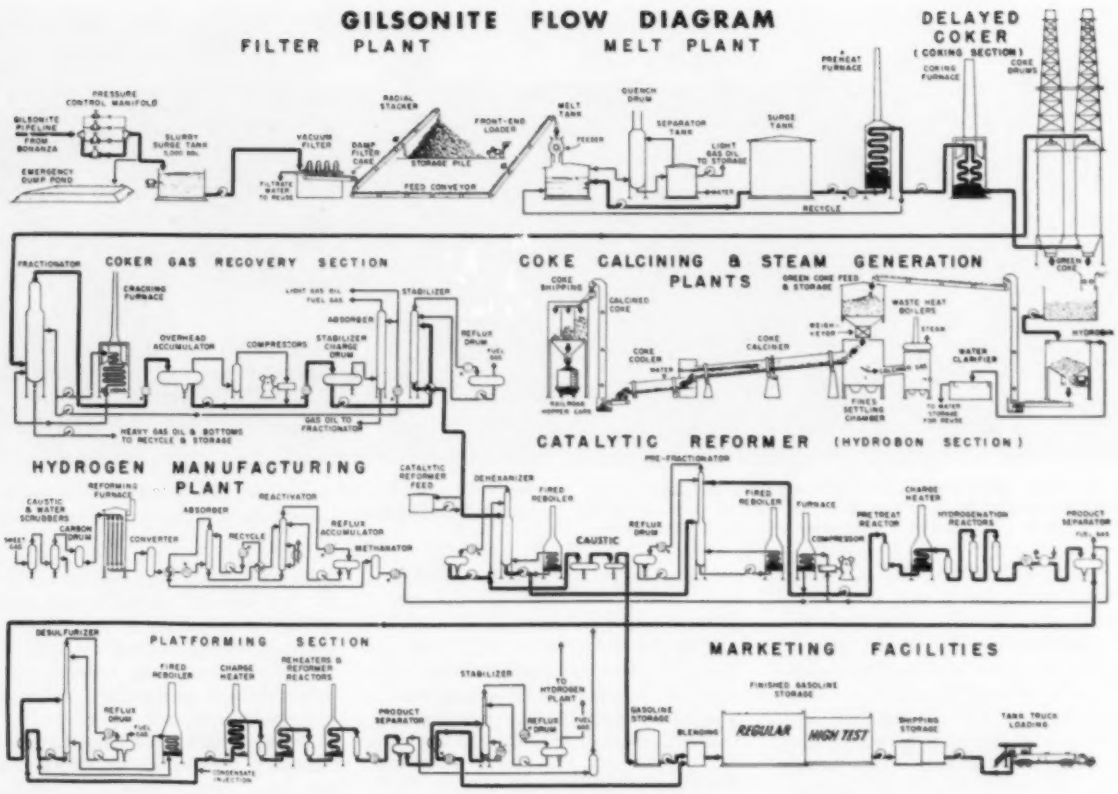


FIG. 3. Gilsonite flow diagram.

Part of the dewatered material is delivered to a stockpile which is maintained at approximately 20,000 tons as a reserve to be used for plant feed whenever necessary. The balance of the dewatered material which has arrived via the pipeline is delivered to a melting tank where it is heated to approximately 450 F, well above its melting point, by means of heat supplied from hot recycle oil produced in the delayed coker.

Delayed Coking Unit

The combined feed to the plant, consisting of 7700 bbl of recycle and 3850 bbl of melted Gilsonite — 11,550 bbl a day — is pumped into a direct fired horizontal updraft heater operating at about 910 F. The output from this heater discharges into a coke drum. Here, the liquid separates from the vapor, coke is formed and precipitates out of the liquid. Coke is continually forming and when the coke reaches a level within a pre-determined distance from the top of the coke drum, the drum is taken off stream and the outlet from the direct fired heater is switched into a clean drum and the coking process continues.

In hydraulic decoking, a high-pressure stream of water (2200 psi) cuts the coke out of the coke drums. The high-pressure jetting apparatus is suspended from derricks mounted on top of the coke drums.

About 50 percent of the coker charge is converted to coke, the balance into liquid and gaseous hydrocarbons. These latter products pass through the drum into a fractionator. Bottoms are recycled to the coker, while a gas oil sidestream is thermally cracked at 985 F. Cracking furnace products are returned to the coker fractionator. Thus, the only products from the fractionator are gas and gasoline, which are taken overhead and sent to a conventional absorbtion-stabilization plant.

Hydrogenation and Reforming

The catalytic reformer consists of three separate but related processes and constitutes the most complex operation in the refinery, although standard for the industry.

The first section of the reformer generates hydrogen which is pumped into the raw gasoline being supplied from the delayed coker to the second section of the catalytic reformer. The hydrogen combines with the nitrogen compounds in the raw gasoline converting them to ammonia which can easily be removed as a gas from the gasoline. The nitrogen compounds must be removed from the raw gasoline, or they would destroy the catalyst in the third section of the catalytic reformer.

The catalytic reformer operation is unusual in that it does not produce enough hydrogen to satisfy its own requirements. Hydrogen is being produced from the process gas, to make up the deficiency caused by the high olefin and nitrogen content of the coker naphtha.

Raw material is converted into finished gasoline in the third section of the catalytic reformer. Here propane and butane are also produced which are returned to the hydrogen generation section to make hydrogen.

Coke Calciner

In this plant, water, volatile and combustible materials are removed from the green coke. This is done in a sloping rotating kiln 10 ft in diameter and 180 ft long. As the kiln turns at about one revolution per minute, the green coke is fed into the upper end and slowly gravitates to the lower end. By the time the coke reaches the end, the moisture, volatile and combustible materials have been removed by heat. The hot, calcined coke passes through a cooler which is another rotating drum 8 ft in diameter and 80 ft long which turns at about three revolutions per minute.

The coke is shipped in covered hopper-bottom cars, primarily to northwestern markets. ★ ★ ★

J. C. Raaen

How Researchers Can Work Effectively

An idea factory needs ideal conditions . . . you must have an organization that upgrades scientists and engineers as well as products to step up achievements

INCREASING productivity of a human being requires a delicate touch. There are times to push . . . times to pull . . . but most of the time you must lead.

Two reasons why we have had to pay more attention than the average medium-sized company to the best ways to lead scientific employees into more and better output are:

1. Research results are our only products. We'll go out of business when results stop coming out of our labs.

2. We are in direct competition with some of the largest corporations in the United States. They, like us, want to hire and keep top-notch scientists and engineers. We don't care if our competitors are bigger than we. We do care if they outdo us.

We separate a program to improve productivity into three basic divisions: Surroundings, administration, and information.

Surroundings is the physical area . . . the brick, steel and glass shell . . . within which scientific manpower works and the tools with which it works.

Administration is control and direction of research departments.

Information is the facts management needs to make decisions and ways to transmit the data.

Where We Work

Let's look at surroundings. As you know, a research man's most valuable asset is time . . . . time spent actually solving problems. So we have done our best to eliminate the distractions that waste time and interfere with productive work.

Well designed buildings and proper equipment pay dividends in productivity. Our new laboratory buildings at Des Plaines (opened in 1955) have paid off.

Patent disclosures are a measure of the productivity of a research staff. Since moving to Des Plaines the number of patent disclosures recorded by research personnel has increased over 50 percent. In one period the number of disclosures was twice the old average.

Percentage figures alone mean little. However the record shows that we are one of the top companies in terms of the annual total of petroleum process patents.

Physically, our buildings are typical of modern laboratory buildings except that we probably have a larger percentage of space devoted to offices. We placed all laboratories along the north side and offices along the south side of the building. The separation was made primarily for economy in contruction.

The saving is apparent when you realize that it costs $54 a square foot to build and equip a lab with or without offices and but $18 a square foot for an office without lab utilities.

The slight physical separation of office and laboratory also provides a change in surroundings. It helps our men shift mental gears when, after working in the lab, they sit down to do purely creative thinking.

How We Work

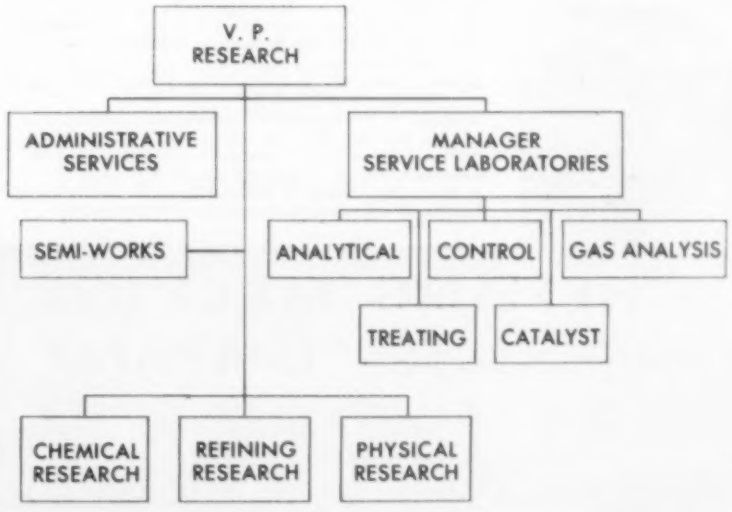
Our organization differs from most in that we have three research directors . . . each autonomous in his field . . . . instead of one. Our research is such that it can logically be divided into three sections: Chemical, refining, and physical. There is enough activity in each area to warrant the full attention of a research director. (See chart.)

Each of the three research directors reports to the vice president in charge of research. Administrative services under the vice president's direction are personnel, clerical, safety, and the like. They also include library, photographic lab, and building maintenance.

Five specialized laboratories are directed by one manager, who reports to the vice president.

Two functions are combined in this department for the sake of economy and efficiency. The service labs do the more or less specialized analytical work for our licensees, normally performed by a typical technical service laboratory. And, because much of this is identical, with the analytical work required by the research laboratories, the service labs also handle this research job.

The semi-works division provides the manpower required to tend continuous research experiments — on bench scale plants — in those hours when the laboratories are unoccupied.



Colonel Raaen is vice president, research, Universal Oil Products Company, Des Plaines, Illinois. This article is based on a paper "Effective Utilization of Scientific Manpower," given before the American Management Association.

Our safety regulations require that no less than two people are present in a room housing running plants. The semi-works plants minimizes this requirement. Most of this work is repetitive and semi-skilled so does not require an engineer or chemist except for day-time supervision and overall direction.

We have a total of 237 research people: 27 percent have bachelors' degrees; 5 percent have masters' degrees; 8 percent have doctorates. The remaining 60 percent are non-degree people, but are skilled in their jobs. Many are working toward degrees in evening schools.

This is how those people are organized: Each of the three research directors is a PhD. Each heads a research department composed of a number of research teams. Each team is headed by a coordinator who generally is a PhD.

Number of workers on a team varies with the nature of the assignment. But, a typical team might consist of five men, one of whom has a master's degree or is a newly-hired PhD undergoing indoctrination. One or two of the team members may have bachelors' degrees and the remainder are experienced non-degree men.

The system is flexible so a research director can run his operation in the best way to get results. And, however the teams are organized, there is one principle: PhD's do not do the work of a BS . . . . and a professional man is not a bottle-washer.

What We Seek

To know what to do with a research department like this you must have a program to send and receive information.

The most important fact we communicate to our scientific people is the basic policy that we will investigate anything in the petroleum and related chemical fields. *Providing* successful completion will contribute to the welfare of the company and those it serves.

Do you think this sounds like a check rein on creative research? Actually, it is not. For one thing, there is a wide, wide area of research where a little more information will make a definite contribution to better petroleum refining. For another, it is not unusual for an applied research project to lead into pure research to provide the extra bit of knowledge needed for success.

We are quite willing to shoot for big stakes. But we are not willing to fritter away money when there is no reasonable possibility that we'll gain anything significant.

We try to keep our research people fully informed on the economic implications of their work as well as the actual costs of doing the work. This is contrary to the prevailing theory that researchers must not be bothered with anything concerning the dollar sign. We try to keep them balancing the cost of their work against the value of the results. In short they must stay within a budget and still produce results.

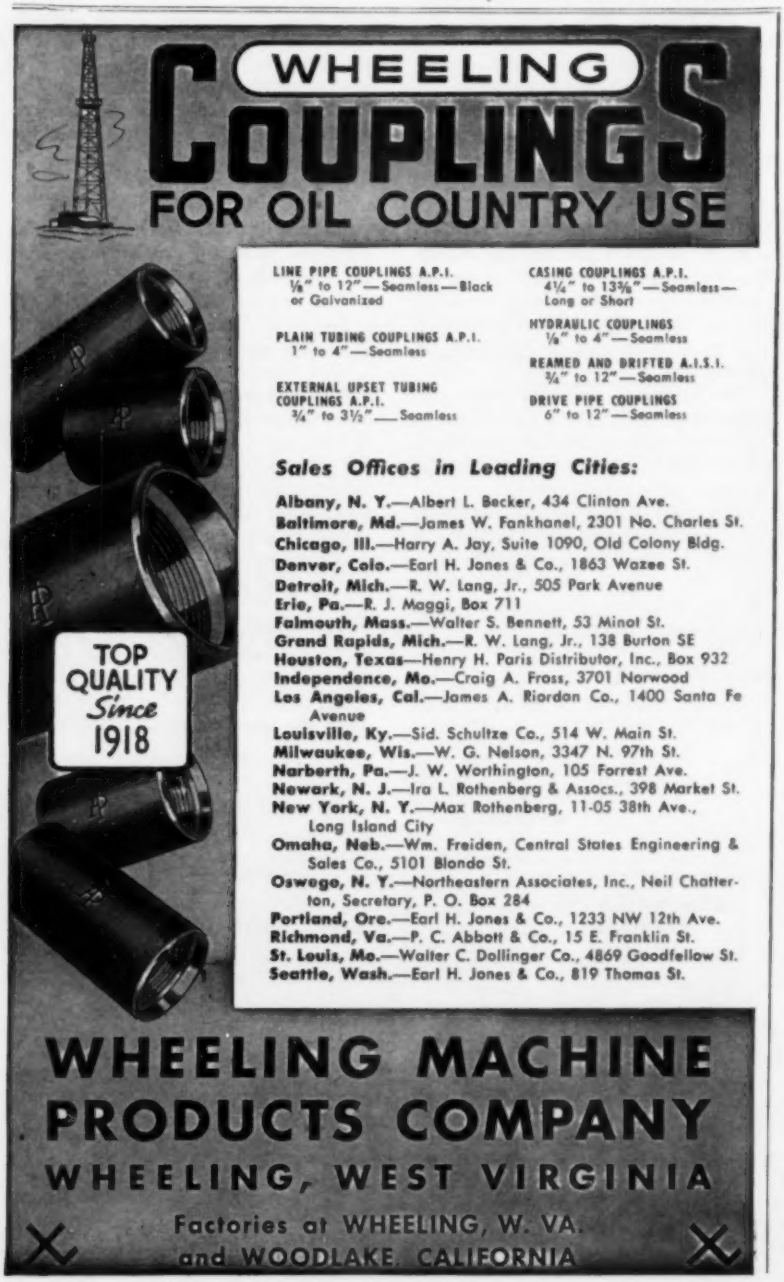
Two-Way Communications

Thorough two-way communication is required to make such a research philosophy work. Management must know what the researchers can accomplish and the research men must know what management requires.

Our two-way process works this way: Each of our research directors meets weekly with his supervisors to review specific projects and day-to-day operations.

Each two weeks the director of one of the research departments conducts a meeting in which all projects of the department are reviewed (historical). All interested research and engineering groups are invited to attend.

Everyone in the department from research director to newest technician discusses his phase of the work. Although not quite a free-wheeling "brain-storming" session, everyone is encouraged to suggest possible solu-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tions to the problems presented.

The meetings pass information up from the labs to the directors for later transmission to management. They stimulate the development of each individual — by exposing a less experienced man to problem-solving methods of more experienced researchers and requiring him to explain his role in the work. They keep other departments abreast of the research picture.

Formal participation at these meetings of other specialists within the company is often requested . . . . primarily from engineering, sales, service, and market research. New marketing opportunities — new competitive processes — are brought to the attention of research people. Commercial value of proposed research projects can be weighted by those who will later have the design task.

Each two weeks the three research directors meet with the vice president for a general discussion of administra- and technical matters. Here the research director who most recently held a biweekly department meeting describes the department's long-range goals and problems that can be expected (what he sees in the crystal ball). It is not unusual for one of the other directors to suggest an approach that results in solution of a problem.

The research directors also make up another very important body — the committee on PhDs. Its function is careful screening of those men considered by the personnel department to be good candidates for major research posts. The committee must give its unanimous approval before any PhD can be hired.

We believe this sceerning is essential. Any Doctor of Philosophy working in one of our research posts carries considerable responsibility. Our research directors are the men most qualified to decide whether a candiate measures up to the requirements.

We constantly try to upgrade our men, increase their ability, provide them with more information relating to their work.

At least once a month we sponsor the appearance of an authority on some phase of research. The lecture is held during business hours and is open to any member of the research and engineering staffs who cares to attend. Purpose is to expose our men to new thinking, to widen their views, to stimulate their thinking.

Similarly, we encourage active participation in technical societies. We frequently send out top people on field trips in the U. S. and even abroad.

Salary has important bearing on the productivity of scientific people. We endeavor to be realistic in what we pay our people. When the hiring rate of inexperienced research people is increased we adjust the salaries of the older employees to reflect the change. We believe it unfair to let the salary range level off. We think our turnover rate reflects the wisdom of a rational attitude . . . . both on our part and on the part of our scientific people.

Our turnover rate is about 1/10 of 1 percent per year. Compare this with the national average of 3 to 5 percent.

I would like to add one final point: I've learned personally that no matter how good your productivity-stimulation program is, you have to get out into the lab yourself . . . to see whether the program is up to date.

A daily visit through the research laboratories doesn't take much time. But, it can be the most valuable time of the day. It is surprising how much a little indication of management interest in the researchers' work stimulates your people.

What I have described is an operation based upon our best thinking to date. But we constantly review our methods to make sure we're not overlooking a better method. Research is our business . . . we think it wise to research our research constantly, particularly insofar as the effective utilization of scientific manpower is concerned. * * *

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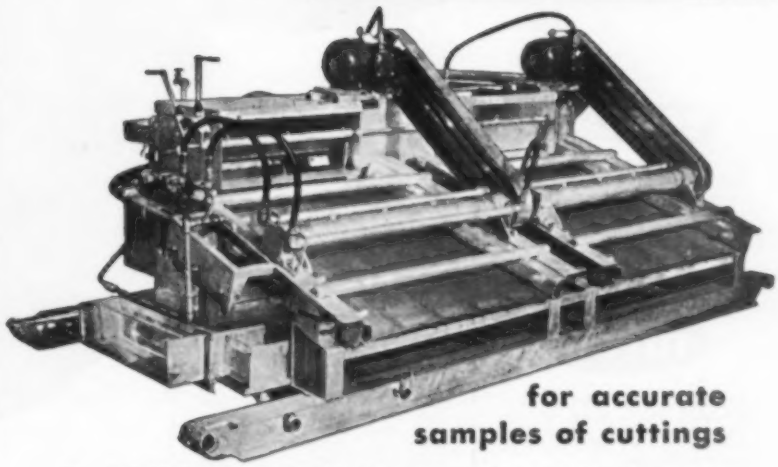

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Management Personals

M. M. Stephens

W. I. Powell

Maynard M. Stephens was appointed Dean of Midwestern University, Wichita Falls, Texas, a school of petroleum and physical sciences. He is also the owner of the consulting firm Associated Petroleum Engineers and an independent oil producer. He will continue in the consulting business.

William I. Powell, Washington attorney, will join the staff of the Independent Petroleum Association of America in Washington. Formerly associated with the American Mining Congress in Washington for eight years, Powell is thoroughly familiar with tax and legislative problems similar in nature and scope to those of the petroleum industry.

Major General John R. Gilchrist, USAF (Ret.), has joined Tidewater Oil Company as administrative vice president for organization planning and development.

Gerald E. Sherrod was named senior petroleum engineer of The First National City Bank of New York. Formerly he was associated with the Texas Pacific Coal & Oil Company of Fort Worth, Texas, as staff engineer.

John H. Loudon was elected chairman of the board of Shell Oil Company. He succeeds **Sir Francis Hopwood,** who retired. **F. J. Stephens** was elected to fill the vacancy on the board resulting from Hopwood's retirement. Loudon is president of the Royal Dutch Petroleum Company and chairman of the board of the Shell Caribbean Petroleum Company. Stephens is a managing director of The "Shell" Transport and Trading Company, Limited, The Shell Petroleum Company, Limited, and N. V. De Bataafsche Petroleum Maatschappij.

J. H. Loudon

F. J. Stephens

C. W. Hamilton, vice president, Gulf Oil Corporation and chairman of the board, Gulf Eastern Company, London, England, has retired.

DEATHS

John C. Askam, 63, assistant to the vice president of the Ohio Oil Company, died in his home July 29 of a heart attack.

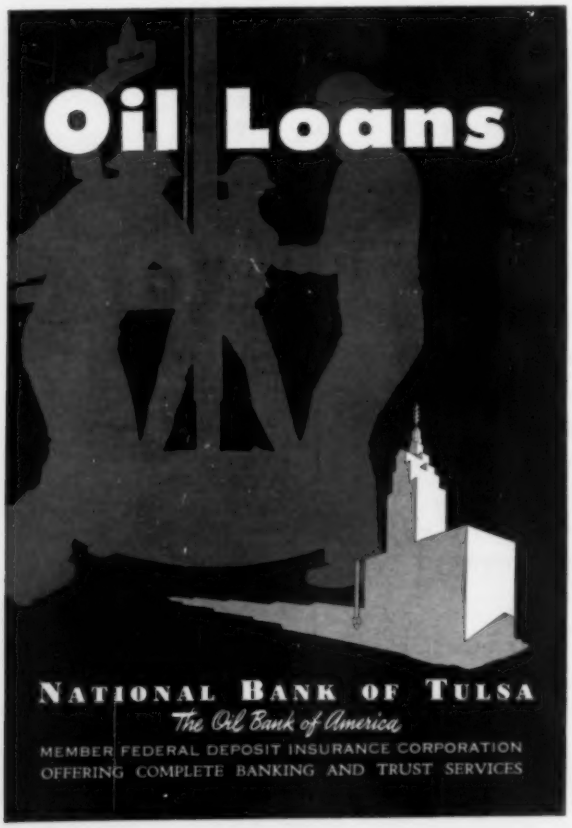
W. D. Moore passed away after a short illness on July 5 in Dallas, Texas. He was manager of Parkersburg Rig and Reel Company's branch warehouse at Hobbs, New Mexico.

Edwin Morris Gearke, 41, regional sales manager for the Mid-Continent area for Baash-Ross Tool Company died July 16, at his home in Houston, Texas.

Walter C. Kerrigan, 65, assistant to the president of The International Nickel Company of Canada, Limited, and its United States subsidiary, The International Nickel Company, Inc., died July 16 at New Brunswick, New Jersey, after an illness of several months.

Joseph R. Minevitch, 65, president of J. R. Minevitch and Associates, Inc., died of a heart attack at his home on July 3. He came to this country in 1906 from Russia and was educated at Massachusetts Institute of Technology and Tufts University. He was a member of the Class of 1916 at M.I.T.

Edmond G. Benoist, vice president and general commercial manager of Automatic Electric Company, was killed July 12 when his auto collided with a moving freight train in a driving rain near Bridgman, Michigan.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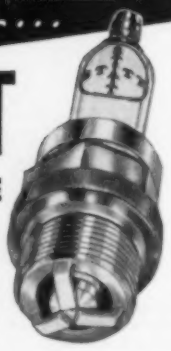

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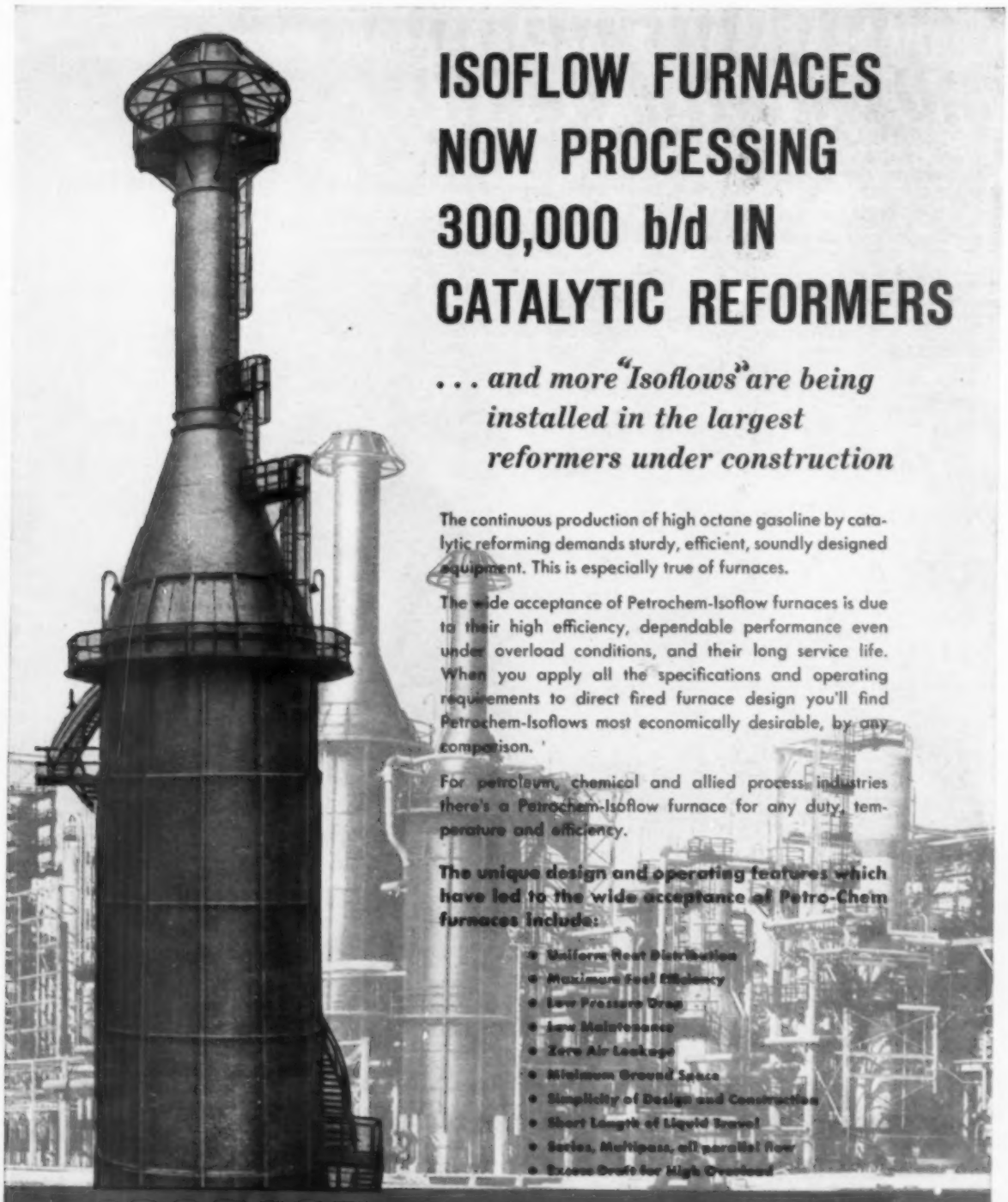
COLUMBUS 1, OHIO
STITT MAKES HEAVY-DUTY, INDUSTRIAL-TYPE PLUGS!

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD



ISOFLOW FURNACES NOW PROCESSING 300,000 b/d IN CATALYTIC REFORMERS

. . . and more "Isoflows" are being installed in the largest reformers under construction

The continuous production of high octane gasoline by catalytic reforming demands sturdy, efficient, soundly designed equipment. This is especially true of furnaces.

The wide acceptance of Petrochem-Isoflow furnaces is due to their high efficiency, dependable performance even under overload conditions, and their long service life. When you apply all the specifications and operating requirements to direct fired furnace design you'll find Petrochem-Isoflows most economically desirable, by any comparison.

For petroleum, chemical and allied process industries there's a Petrochem-Isoflow furnace for any duty, temperature and efficiency.

The unique design and operating features which have led to the wide acceptance of Petro-Chem furnaces include:

- Uniform Heat Distribution
- Maximum Fuel Efficiency
- Low Pressure Drop
- Low Maintenance
- Zero Air Leakage
- Minimum Ground Space
- Simplicity of Design and Construction
- Short Length of Liquid Travel
- Series, Multipass, all parallel flow
- Excess Heat for High Overload

PETROCHEM-ISOFLOW FURNACES

UNLIMITED IN SIZE . . . CAPACITY . . . DUTY

PETRO-CHEM DEVELOPMENT CO., INC. • 122 EAST 42nd St., New York 17, N. Y.

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LAUGH with BARNEY

No one is a complete failure so long as he can serve as a horrible example.

* * *

After the ceremonies were over celebrating the unveiling of a bust of an old college professor, a pretty young lady walked up to him and said: "I hope you appreciate me," she cooed. "I came 50 miles to see your bust unveiled."

"My dear young lady," replied the gallant professor, "I would travel a thousand miles to see yours."

Recycle Operation . . .

A farmer hired two city boys to work his farm. He put one to milking and the other to plowing. Looking in on the first boy, he found him feeding the milk to the cow. He inquired as to why. "Well, you see," explained Joe, "just as I finished milking her, she stuck her foot in the milk, so I decided I'd better run it through again to clean it."

* * *

Do you know what a tomato juice and Geritol is? A tired Bloody-Mary.

A lot of enterprising young engineers are spending much of their valuable time tinkering with misses in their motors.

* * *

"Sometimes," said the mistress to the new maid, "It will be necessary for you to help me upstairs."

"I understand, ma'am," replied the girl, "I drink a bit myself."

* * *

Barney says that many a man who goes into a bar for an eye-opener comes out blind.

* * *

A man went to a psychiatrist about his brother.

"He walks around all day beating a bass drum," he told the doctor.

"There's nothing abnormal about playing music," said the head thumper. "I myself occasionally play the bass drum."

"From the inside?" asked the worried brother.

* * *

Everyone should learn to drive a car. This is especially true of those who sit behind the steering wheels.

* * *

An oil company had a vice president by the name of Mr. Saxauer. One day a gentleman came into the office and asked the receptionist—"Do you have a Saxauer here?"

The receptionist promptly replied—"oh no, sir—they don't even give us a 10-minute coffee break."

* * *

A real man-about-town is the one who travels in the best circles with the best curves, and knows all the angles!

* * *

Dan B. Mahoney of Oklahoma City is passing out calling cards with "Requisites of a Good Lease Broker" on the back. Barney agrees that a good lease broker:

"Must be a man of vision and ambition, and an after-dinner speaker, before and after dinner guzzler, night owl, work all day and half the night, then drive 200 miles and appear fresh the next day. You must be able to entertain bankers, farmers, cattle men, company landmen, and pet widows without becoming too amorous. Inhale dust, drive through snow 10 ft deep at 10 below, and work all summer without perspiring or acquiring BO. Must be a man's man, a lady's man, a model husband, a fatherly father, a good provider, a Plutocrat, a Democrat, a Republican or a New Dealer, an old dealer and a technician, politician, mathematician, mechanic, carpenter, baby sitter and a notary public. Must be a buying genius, able to anticipate other company plays, a land scout and general information bureau. Must visit clients in hospitals, jails, honky-tonks and beer joints. Contact all buyers in immediate vicinity at all times and be prepared to leave for parts unknown, a distance of not less than 2000 miles, on five minute notice. Must have unlimited endurance, a wide range of telephone numbers in all principal cities, an acquaintance beginning in Maine and ending in California. Must have a good car, an attractive home and belong to all clubs and pay all expenses at home. Must be an expert driver, talker, dancer, traveler, bridge player, poker player, diplomat, financier, capitalist, philanthropist, geologist, lawyer, abstractor, good and fast with a typewriter, an authority on palmistry, chemistry, psychology, dogs, horses, brunettes, blondes and redheads.

Is it any wonder that good lease brokers are hard to find?"

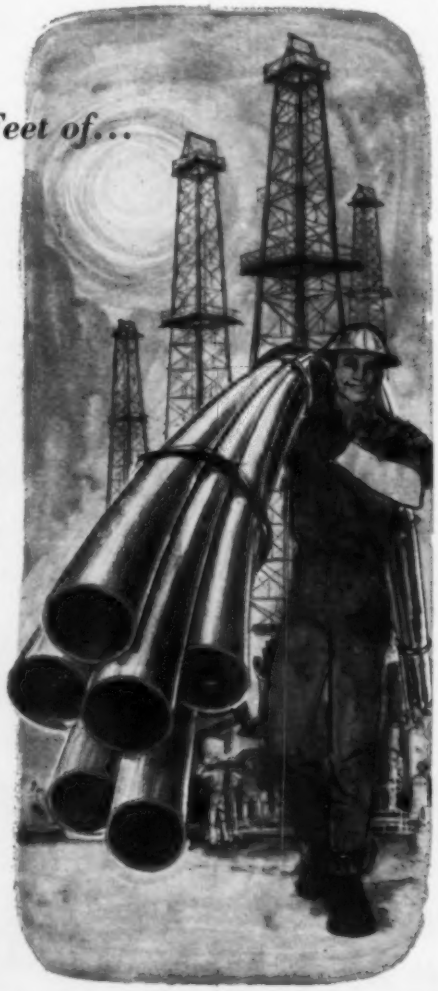
Over One Million Feet of...

KRALOY

HIGH-IMPACT

PVC PIPE

in oil-country use today



This proves that there is no substitute for Kraloy experience.

KRALOY is the most experienced manufacturer of PVC plastic pipe for the petroleum industry. The first polyvinyl chloride lead line installed in this country—at Great Bend, Kansas—was Kraloy Pipe. Kraloy High-Impact PVC today is preferred by production men for maintenance-free service in lead lines and disposal systems. Kraloy customers use Kraloy High-Impact PVC pipe for lead lines, gas lines, and salt water lines because Kraloy normally eliminates (1) sulphur corrosion due to sour crude, (2) paraffin buildup, (3) corrosion and scale, (4) trouble from soil electrolysis.

YOU Benefit From KRALOY'S Quality Control

To insure quality control, random samples of Kraloy Plastic Pipe are tested daily in Kraloy's own laboratory for burst pressure, impact resistance, and tensile strength under standard ASTM specifications.

Kraloy Pipe is Sold Only Through Qualified Supply Stores

Warehouse stocks and sales representatives:

Great Bend, Kansas:
Robinson Oilfield Specialties Co.,
616 Main St.

Houston, Texas:
The Mott Company,
1719 McKenney St.

Tulsa, Oklahoma:
The Becker Sales Company,
2837 Sands Spring Rd.

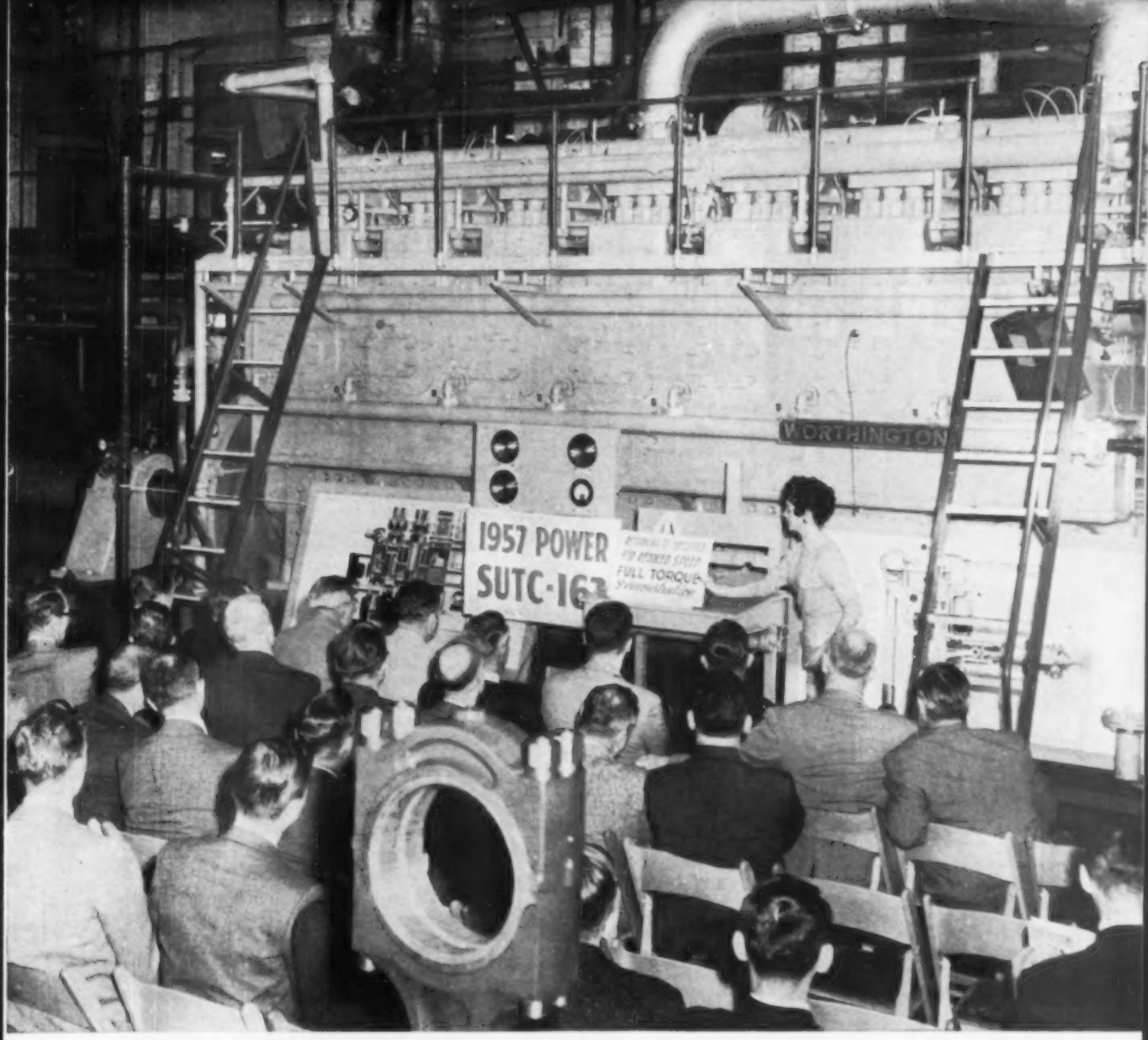
For case histories of actual Kraloy installations, cost comparison tables between Kraloy and other pipe, plus detailed instructions and specifications for all field uses, write to:

KRALOY *plastic pipe co., inc.*

4720 East Washington Boulevard, Los Angeles, Calif.

Subsidiary of the Seamless Rubber Co., a Rexall Drug Co. Subsidiary

SP-100



At 1957 Power Fair, engineers witness proof of...

TURBO-UNIFLO PERFORMANCE

There's no better way to judge the performance of an engine than to see it in operation. That's why more than 250 process and pipeline engineers recently gathered in Buffalo, N. Y., to attend Worthington's 1957 "Power Fair."

Star of the show was the new SUTC TURBO-UNIFLO gas engine compressor. The only two-cycle engine compressor with exhaust powered turbocharging from start-up through full-load, the TURBO-UNIFLO features remarkable stability over the complete range of speed and load requirements.

The audience was impressed by the TURBO-UNIFLO's smooth start and quiet operation (as much as 20 decibels quieter than engines with mechanically driven scavenging systems). Next came the overload demonstration to prove the very conservative engine rating.

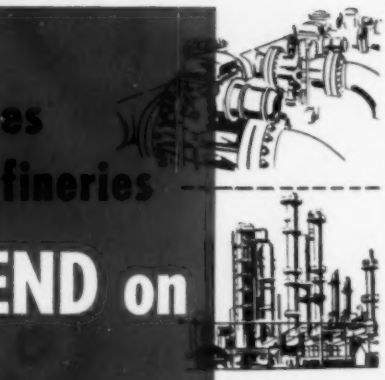
To show stability, engine speed was gradually reduced while maintaining full torque. 320 rpm . . . 270 rpm . . . 230 rpm (at this point someone offered to bet that it couldn't go below 150). But down it went . . . all the way to 105 rpm before reaching its stalling point.

But this is only half the story. Your Worthington representative will be glad to give you all the facts about the new SUTC TURBO-UNIFLO engine. Get in touch with your nearest Worthington district office or write to Section E-73, Worthington Corporation, Harrison, N. J. In Canada: Worthington (Canada) 1955, Ltd., Brantford, Ont. E-73

WORTHINGTON

Pipelines and Refineries

DEPEND on



Line Scale Long Service

VALVES and SEATS!

For all reciprocating pumps, regardless of size, age, or model . . . in Bronze and Stainless Steel to meet every need, providing long service at pressures up to 1,500 P. S. I. and temperatures up to 300°F. Special sizes on request.

- **Nylon Plate** — Insures long life in all fluids, except Phenol, Formic Acid or Concentrated Mineral Acids.
- **Cone Type Spring** — Fully corrosion resistant; cone construction lengthens life of spring, eliminates coil wear.
- **Double Seating Area**—Seating on shoulder and outer rim provides greater seating area and less deformation area.
- **Reversible Valve Plate** — Offers a bonus of double valve life.
- **Quick Change** — Keeper and retainer design provides quick change of spring or valve without use of any tools.

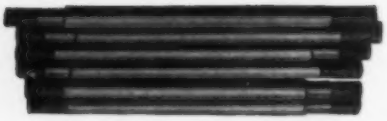
NEW 1957 CATALOG AVAILABLE!

Send for YOUR Copy . . . TODAY!
(Complete with Price Lists)

Line Scale COMPANY, INC.

2734 S. HIGH STREET
OKLAHOMA CITY, OKLAHOMA

Pump rods hard-faced by ThermoSpray Process give 20 times longer service



New Metco Process hard-faced acid sludge pump rods serve as much as 20 times longer than unfaced rods.

A number of oil companies are making important savings in equipment down-time and replacement part costs with the METCO THERMOSPRAY* Hard-Facing Process. Typical of these parts are pump sleeves, as well as the acid sludge pump piston and rods shown here. Operating conditions were severe—rods had to be replaced every 24 hours—new packing every 8 hours. Hard-faced rods now last over 500 hours; packing more than 60 hours. Coatings are extremely dense and non-porous—homogeneous.

The THERMOSPRAY Hard-Facing Process consists of spraying specially developed alloys in powder form with the METCO THERMOSPRAY GUN. No compressed air is required. Coatings have hardness of Rc 30 to Rc 65, depending on the specific THERMOSPRAY alloy used; will outwear hardened steels from 3 to 10 times. Spraying speeds are higher—8 to 10 lbs. per hour—and deposit efficiency far greater (up to 97%)—than with any other type of available equipment. Hard surface depth can be closely controlled and the smooth surface left after spraying requires a minimum of finishing.

Write today for free descriptive Bulletin 126A or a call by a full-time, company-trained, Metco Field Engineer in your territory. Or see your local metallizing job shop.

The following trade names are the property of Metallizing Engineering Co., Inc.: METCO, ThermoSpray.*
**Reg. U.S. Pat. Off.*

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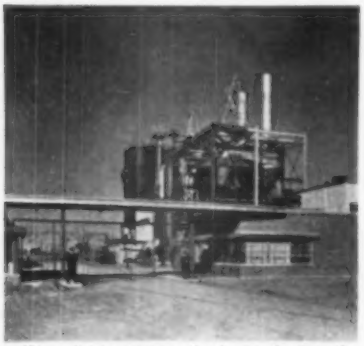
METALLIZING EQUIPMENT COMPANY, LTD.—Chobham near Woking, England

• Industry
• People
• News

The Trade PARADE

New Davison Plant Onstream

The $6,000,000 plant of Davison Chemical Company Ltd., at Valleyfield, near Montreal, Canada, is producing synthetic fluid cracking catalyst for Canadian refineries.



The plant entrance is shown in the picture. The administration building is on the right; spray driers and storage silos can be seen in the background.

The company is affiliated with the Davison Chemical Company Division of W. R. Grace & Co. The Canadian plant is similar in design and identical in product to Davison plants at Baltimore, Cincinnati and Lake Charles, Louisiana.

This large oil well drilling rig, believed to be the first ever to be air conditioned for land use, was assembled by S & R Tool and Supply Co., Houston, Texas, for use in a North African desert. Total area to be cooled, including 10,000 cu ft in engine house and 10,000 cu ft on drilling floor, is surrounded by sheet steel. Engine house is also roofed with the material, while drilling floor is open to the sky. Six evaporative cooling units, employing water to be obtained from well to be drilled, will lower temperature from 139 F desert maximum to constant 80 F within enclosed areas.

W-K-M Breaks Ground For Foundry

Honor of breaking ground for construction on W-K-M's new iron and steel foundry in Richmond, Texas, was bestowed upon J. S. Downs, president of W-K-M, and Judge George S. Roane, county judge of Fort Bend County.

New and modern facilities at the foundry will make it possible to pour approximately 600 tons of steel and 400 tons of iron castings monthly. It will have its own modern chemical and physical testing laboratory complete with facilities for gamma-ray analysis to insure high quality iron and steel castings.

Downs said construction cost is estimated at one million dollars and that production is anticipated at the new facility in about one year. Total employment will be approximately 500 persons.

Castings for W-K-M products consisting of valves and return bends and fittings for refinery use will be poured at the new facility.

Cosasco Expands

Cosasco Division of Perfect Circle Corporation has moved to a new plant with four times the floor space of their former location. The Cosasco Division was formed June 5 last year, when Perfect Circle Corporation acquired the Corona Oil Specialties and Service Company. Products of the division include special nipples which permit entering lines and vessels against pressure, mandrels or tubing hangers, wet plugs and "Unitized" wellheads and various corrosion-control accessories such as coupon holders, water samplers, thermo-couples and hydrogen probes.

Fischer & Porter Mobile Exhibit

Fischer & Porter Company is sending a mobile exhibit of its products on a swing around the country.

Exhibit is housed in a specially constructed stainless steel trailer, completely equipped to give on-the-spot operating demonstrations of dozens of F&P's products before customer groups, technical schools and universities and at meetings of engineering societies.

Drilling superintendents agree: for fast delivery you can't beat Worthington QD (Quick Detachable) sheaves — the original two-piece design.
MV-7-2

WORTHINGTON CORPORATION, Oil City, Pennsylvania

Three Companies Merge Into Yuba Consolidated

Merger of Yuba Consolidated Gold Fields, Yuba Industries, Inc., and the Portuguese-American Tin Company to form a single integrated corporation known as Yuba Consolidated Industries, Inc., and purchase of the Heat Exchanger Division of The Lummus Company, Honesdale, Pennsylvania, has been announced by Yuba's San Francisco headquarters.

Yuba now directs activities of four major manufacturing plants, in addition to California gold mining and Portuguese tin mining operations. Adsco Division at Bufflalo, New York, manufactures heat exchangers, expansion joints, and other plate and structural steel fabrication. California Steel Products Division of Richmond, California, is engaged in engineering and fabrication of heat exchangers, heavy structural items, and processing equipment. Yuba Manufacturing Division at Benicia, California, designs and builds dredges and a wide range of heavy machinery components and products. The new Honesdale organization manufactures heat exchangers, evaporators, condensers, feed water heaters, and allied equipment for the power industry.

Clark Opens New Branch Office

Clark Bros. Co., of Olean, New York, has announced the opening of a new, modern office and warehouse facilities at New Orleans, Louisiana. Clark Bros., are manufacturers of compressors and gas turbines.

ARCCO

NOW SPECIFIC GRAVITY RECORDING OF LIQUIDS AT ANY DISTANCE

RECORDING TRANSMITTER

Accurate long-distance transmission of specific gravity recordings is no longer a problem with any of the new RMT Models of Arcco-Anubis Recording Gravitometers for recording and transmitting liquid gravity records. These instruments combine the mechanism of the standard Arcco Liquid Gravitometer with a metameter telemeter transmission system which records and transmits the specific gravity record to control room or other remote location. The interconnecting line may be any two-wire electrical circuit or its equivalent: private wires, telephone circuits, carrier current channels, or radio (VHF or UHF).

The range of the standard instrument is .15 or larger, but instruments with ranges of .10 or .05 can be supplied. Charts are available for more than 75 different ranges of Specific Gravity or Degree A.P.I. Special ranges can be furnished at slight additional cost. Request Bulletin No. 111-R3 for complete details.

RECORDING RECEIVER

AMERICAN RECORDING CHART CO.
3113 E. 11th St. • Los Angeles 23, Calif.

SEND for BULLETIN No. 111R2B

NEWS NOTES

New district "on the spot" sales and service center for Franks Division, Cabot Shops, Inc. recently opened at Odessa, Texas, with an "open house" and barbecue attended by over 1500 West Texas operators. Shop will stock parts for both the Franks line of well servicing and drilling units and Cabot pumping units and is large enough to repair, adjust, or overhaul four Franks units at one time.

ELECTRODATA DIVISION OF BURroughs Corporation has completed a six-fold enlargement of its Pasadena plant, now totaling 250,000 sq ft. The $4-million plant is the west's largest engineering and production facility for electronic computers.

RAYBESTOS-MANHATTAN, INC. has purchased The Graef Engineering Company and has established a Pacific Coast Division to manufacture "Teflon" and "Raylon" products. Arthur W. Byxbee was appointed general manager.

AFTER 20 YEARS, OTIS PRESSURE Control has changed its corporate name to Otis Engineering Corporation. "Although our old name was in fact virtually our reputation, we believe that the new name will more accurately reflect the scope of our company and the production tools we manufacture and market," Robert H. McLemore, president, said,

TOTALLY OWNED SUBSIDIARY, Philadelphia Pump and Machinery Company, will be merged into and become the Philadelphia Pump Division of American Meter Company, with headquarters in Philadelphia. Robert J. Browne will be chief engineer and general manager of the new Philadelphia Pump Division.

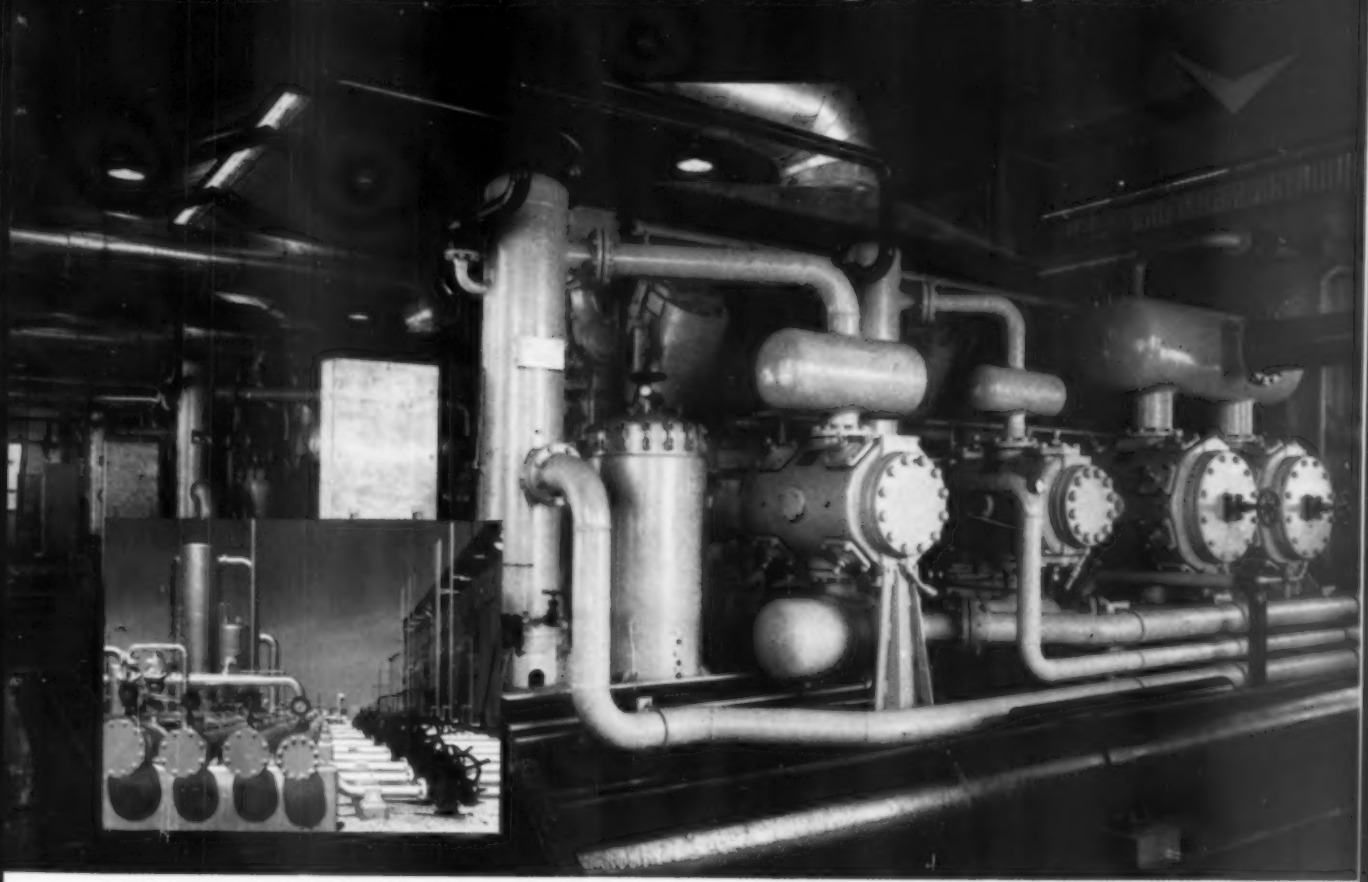
MISSION MANUFACTURING COMpany has begun construction of its new $2.25 million plant in Houston. Appearance-wise, the new plant is being built with accent on beauty. The main building will make extensive use of brick and aluminum siding. It will be windowless and fully air conditioned.

UNION CARBIDE CHEMICALS Company, Division of Union Carbide Corporation, plans to build a technical service laboratory near Tarrytown, New York. It is expected that the laboratory will be completed early in 1959.

UNION TANK CAR COMPANY WILL acquire all the assets of Phoenix Manufacturing Company, including the stock of its wholly owned subsidiary, Graver Tank and Manufacturing Company, Inc.

BETHLEHEM SUPPLY COMPANY opened their first new store in Utah at Blanding this month. D. W. (Wayne) Crossan will be in charge of the store operation and J. C. McDaniel will be in the store.

BEAIRD-INGERSOLL-RAND Packaged Compressor Plant



REEF FIELDS GASOLINE CORPORATION'S Good Field Compressor Station—equipped with five Beaird-Ingersoll-Rand 660 h.p. 12SVG packaged compressors . . . Young radiators and all necessary controls. Other sizes 120 to 660 h.p.

Boost Gas . . .

PACKAGED COMPRESSORS HANDLE 278 SPRAYBERRY WELLS

Reef Fields Gasoline Corporation built the Good Field Compressor station to boost separator gas from low pressure wells to a natural gasoline plant sixteen miles away. Originally planned to handle Good Canyon Reef Field, the station has now been expanded to gather gas from the Jo-Mill Sprayberry Field. Five Beaird-Ingersoll-Rand 12SVG 660 h.p. packaged compressors have been installed to handle this increased load.

Picking up from the wells at 3 psig. the units boost the gas through three stages of compression to discharge at 600 psig. At present 278 wells are tied into the station which has a total volume of 18,000 MCF per day. Of this capacity, the five Beaird units recently added, are handling 12,000 MCF per day.

Packaged compressors were selected for the Good Field Station as total compressor requirements cannot be determined until the Sprayberry field is fully developed. Also the field is expected to have a relatively short life. As production tapers off, the units can be moved one at a time with little or no change to other service. The remaining units can be kept fully loaded in this manner until the field is depleted.

Let us give you all the facts about the economy of installing multiple Beaird-Ingersoll-Rand packaged compressor plants.

BEAIRD
another AMF product
PACKAGED COMPRESSOR PLANTS

LOWEST COST PER HORSEPOWER INSTALLED

THE J. B. BEAIRD COMPANY, INC.
Shreveport, Louisiana
A subsidiary of American Machine & Foundry Company

SHREVEPORT, LOUISIANA • *Sales Offices: Dallas, Houston, Corpus Christi and Midland, Texas • New Orleans, Louisiana • Tulsa, Oklahoma • Denver, Colorado Los Angeles, California • Caracas, Venezuela, and Cie. Ingersoll-Rand, Paris, France.*

TO SERVE YOU BETTER

"We have to know our business to serve your business." That's an unwritten slogan at Texas Employers' Insurance Association. Service in any industry is rendered through people and *superior* service is provided by those most highly trained in their respective professions.

Texas Employers' leading position in its industry is due largely to its plan of sponsoring and encouraging specialized education and training programs for all levels of its management and employees... equipping them with the knowledge and skills necessary to serve employers of labor in Texas more efficiently

Complete specialized training courses are conducted by the Claims, Engineering and Sales departments, with other departments carrying on informal training sessions for their employees. Other company-sponsored programs include courses offered by the Insurance Institute of America, the American Mutual Insurance Alliance, the American Institute for Property and Liability Underwriters, the American Management Association and other recognized national groups.

People who know their business and who can serve your business efficiently — this is one more of the advantages offered by the Texas Employers' Insurance Association... advantages which have provided **SERVICE, SECURITY** and **SAVINGS** to Texas business and industry for over 43 years.

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Symbol of leadership in
WORKMEN'S COMPENSATION
Insurance

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Outstanding opportunities in Sales, Claims, Engineering and other departments for qualified young men.

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Trade Parade

A NEW MANUFACTURING FIRM which will build lease automatic custody transfer units has been formed by a Tulsa mechanical engineer. Major Engineering Company is engaged in the design, manufacture, and sale of skid mounted, completely unitized meter type lease automatic custody transfer (LACT) units. Ralph W. Hill is president.

COLLINS RADIO COMPANY HAS announced that it will begin construction of a 235,000 sq ft manufacturing plant in Cedar Rapids, Iowa, at an estimated cost of $2,750,000 within the next several weeks. The new facility will house the company's fabrication activities, including sheet metal, machine shop, engineering model shop and painting and plating departments and will be located on a 90-acre tract. Occupancy is scheduled for early 1959. Collins also has announced the immediate construction at Richardson, Texas, a Dallas suburb, of 128,000 sq ft engineering laboratory, at a cost of $1,700,000.

THE CORPORATE NAME OF NORTH American Instruments, Inc., has been changed to Northam Electronics, Inc. The company is a subsidiary of Norris-Thermador Corporation, with headquarters in Los Angeles.

EXECUTIVE OFFICES OF ROBERTshaw-Fulton Controls Company, now at Greensburg, Pennsylvania, will be relocated in early fall in Richmond, Virginia.

FORMATION OF A NEW SYSTEMS Division in an organizational expansion of Beckman Instruments, Inc., has been announced. Headquarters and manufacturing facilities will be established at Anaheim, California.

John F. Bishop, general manager of the Beckman Scientific Instruments, Berkeley and Process Instruments divisions, will head the Systems Division, with T. C. Fletcher as director of engineering and manufacturing, and W. E. Rianda as director of marketing.

COLBY, INC. OF HOUSTON, TEXAS, has been appointed export agent, except for Venezuela, Canada, Alaska and Hawaii, for the rectifier section of the Electrical Mechanical Division of Good-All Electric Manufacturing Company, Ogallala, Nebraska.

PEOPLE

Barney R. Doak has been named manager of Canadian sales and service for W-K-M, Division of ACF Industries, Incorporated. Doak, who was formerly with

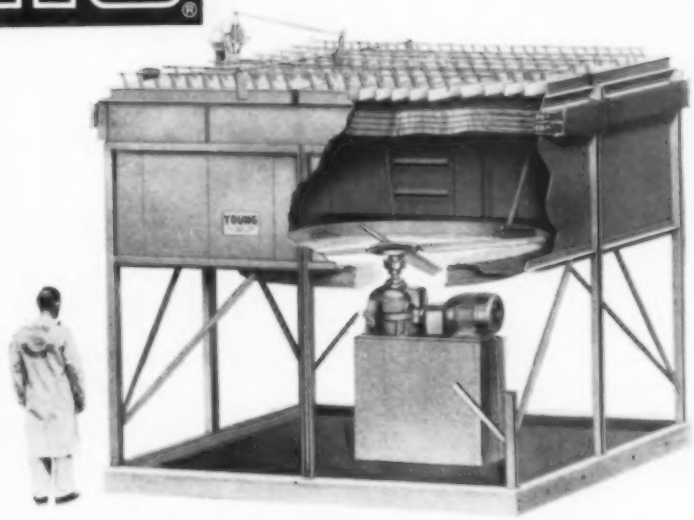
B. R. Doak

R. L. Rice

Parkersburg Rig and Reel Company as a sales engineer, will cover the industry in Canada with headquarters in Calgary.

Robert L. Rice has been promoted to general sales manager of Fischer & Porter Company. He joined F & P in 1950 as a sales engineer, becoming sales manager of the Cincinnati office a year later.

HC HORIZONTAL CORE UNITS by Young



Design features that make this HC® unit a dozen ways better

Young atmospheric coolers are capable of meeting a wide range of cooling requirements. Illustrated is one of several units cooling natural gas at a pipeline compressor station. Cutaway shows some of the superior construction features.

1 • **ROUND TUBE CORES** for liquid pressures up to 150 psi or greater. Gas or vapor cooling up to 2500 psi and greater are obtainable.

2 • **MONOBLOC TUBE CONSTRUCTION** of superior design provides greater "bursting strength" with increased heat transfer surface.

3 • **REMOVABLE COVER PLATE** on end tanks for easy inspection and maintenance on cores operating up to 150 psi; removable plugs opposite each tube on cores for higher operating pressures.

4 • **TUBE-FIN ASSEMBLY.** The positive mechanical bond of fin to tube ensures maximum performance, unaffected by hot and cold cycles.

5 • **HORSEPOWER REQUIREMENTS** are lower because of decreased air flow resistance.

6 • **BAFFLE PLATE ARRANGEMENT** allows for more liquid passes—higher tube velocity—consequently takes better advantage of cooling surface.

7 • **FRAME.** Uprights and braces from heavy gauge channel steel; cover plates of heavy gauge sheet steel.

8 • **BRACING.** Plenum chamber is braced at intervals for structural rigidity, and to dampen vibration which may be caused by air turbulence.

9 • **TUBE REPLACEMENT,** where operating conditions necessitate, on both Monofin and Monobloc construction is easily accomplished.

10 • **ASME** code specifications can be furnished on cores where required.

11 • **FINS.** Straight in-line design reduces air resistance, provides for greater cleanliness.

12 • **PLENUM CHAMBER** designed to take full advantage of all heat transfer surfaces, equalizes distribution of air.

OIL FIELD AND PIPELINE REPRESENTATIVES

1. Central Station Equipment Co. Tucson, Arizona
2. Flournoy & Everett, Inc. Downey, California
3. Jones and Laughlin Bradford, Pennsylvania
4. J. R. Meek Company Tulsa, Oklahoma, Houston, Texas
5. Frank Walz Denver, Colorado
6. Dutton-Williams Bros. Ltd. Calgary, Alberta, Canada
7. H. J. Young Muskegon, Michigan

"WHERE QUALITY COUNTS"

Write for catalog 550 Dept. 217-J

Young RADIATOR COMPANY

RACINE, WISCONSIN

Creative HEAT TRANSFER ENGINEERS

Executive Office: Racine, Wisconsin, Plants at Racine, Wisconsin, Mattoon, Illinois

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

Purchasing agents agree: when you need fast delivery, you order Worthington QD (Quick Detachable) sheaves — the original two-piece design. MV 7.10

WORTHINGTON CORPORATION, Oil City, Pennsylvania

Trade Parade

Everett W. Lundy has been appointed general sales manager, Peerless Pump Division, Food Machinery and Chemical Corporation, Los Angeles and Indianapolis.

E. W. Lundy

C. G. Danielson

Carl G. "Dan" Danielson, formerly with Midwestern Engine & Equipment Company, Inc., Tulsa, has been named manager of the Houston branch of Midwestern Pipe Line Products Company.

Richard S. Funk has been named advertising manager of the recently-formed Mining and Mineral Products Division of Great Lakes Carbon Corporation.

Sam Gurley Jr. has been appointed vice president of sales for Olin Aluminum. He had been vice president-sales of H. K. Porter Co., Inc.

L. S. Beeler has been appointed assistant manager of chemical and petroleum market sales for Reynolds Metals Company.

James H. Whorton has been transferred to Cameron Iron Works, Ltd., Leeds, England, as production control manager.

William J. Burke has been appointed director of sales for the Texas-U. S. Chemical Company.

Gay V. Land has been appointed vice president, oil department of the Climax Molybdenum Company.

Dr. Raymond Wynkoop has been appointed manager of sales of Catalytic Construction Company.

Charles E. Meginnis has been appointed sales manager for industrial chemicals for the Davison Chemical Company Division of W. R. Grace & Co.

C. E. Meginnis

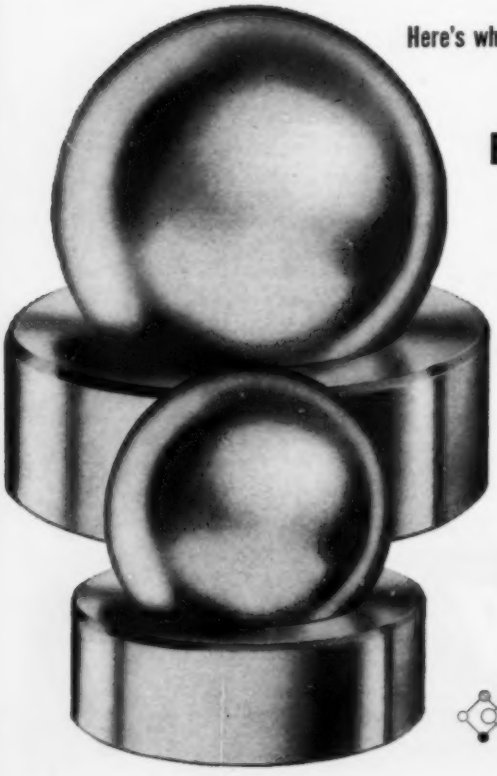
J. W. Knowlton

The Martin-Decker Corporation has announced the appointment of **Jack W. Knowlton** as sales manager. He will be responsible for sales and service of the company's products, both domestic and foreign.

Edwin L. Paramore has been named a regional vice president of Halliburton Oil Well Cementing Company. His responsibilities will include the Shreveport, New Orleans, Houston and Corpus Christi divisions of the company.

John L. Tullis has been advanced to vice president and assistant general manager of The J. B. Beaird Company, Inc.

Milford H. Luttrell has been named general sales manager of the Walworth Company.



Here's what you get with

KENNAMETAL* BALLS and SEATS

EXCEPTIONALLY HIGH RESISTANCE TO

- Fluid Cutting
- Wear • Corrosion
- Electrolytic Action
- Ball Pounding
- Ball-on-Seat Shock

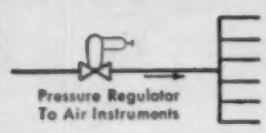
If you have a problem well, or just want longer life, less pump downtime, ask your pump service man to install Kennametal API Balls and Seats. They will cost you less in the long run. KENNAMETAL INC., Latrobe, Penna.

*Trademark

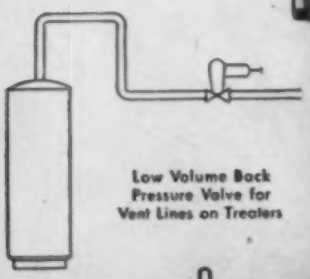
INDUSTRY AND KENNAMETAL ...Partners in Progress

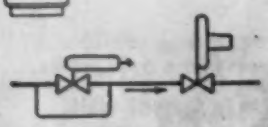
1st Choice FOR POUNDS TO POUNDS SERVICE

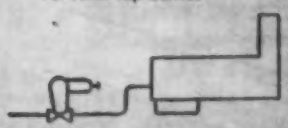
FISHER®

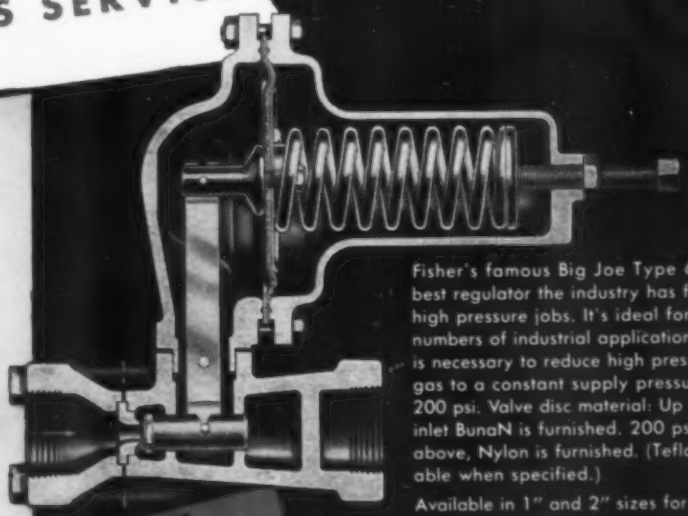

Pressure Regulator To Air Instruments

Pressure Regulator For High Pressure Gas Bulk Storage


Low Volume Back Pressure Valve for Vent Lines on Treaters


Pressure Regulator For Farm Tap Service


Reducing Valve for Heater Fuel or Treater Furnace Fuel



TYPE 630 FOR INLET PRESSURES UP TO 1500 psi

Fisher's famous Big Joe Type 630 is the best regulator the industry has for rugged high pressure jobs. It's ideal for countless numbers of industrial applications where it is necessary to reduce high pressure air or gas to a constant supply pressure of 5 to 200 psi. Valve disc material: Up to 200 psi inlet BunaN is furnished. 200 psi inlet and above, Nylon is furnished. (Teflon is available when specified.)

Available in 1" and 2" sizes for inlet pressures up to 1500 psi and outlet pressures 5 psi to 200 psi.

TYPE 620 FOR INLET PRESSURES UP TO 750 psi

For real economy the Fisher Type 620 pounds to pounds regulator is used on same applications as 630 "Big Joe" where pressure and flow requirements do not exceed 750 psi and reduced pressure not above 100 psi.

For inlet pressures up to 750 psi with malleable iron or cast steel body; up to 150 psi with cast iron body. Outlet pressure ranges: Type 620—3 to 60 lbs. (4 springs). Type 621—3 to 100 lbs. (5 springs). Valve disc material: BunaN when inlet pressure is 300 psi or less, and Nylon when inlet pressure exceeds 300 psi.

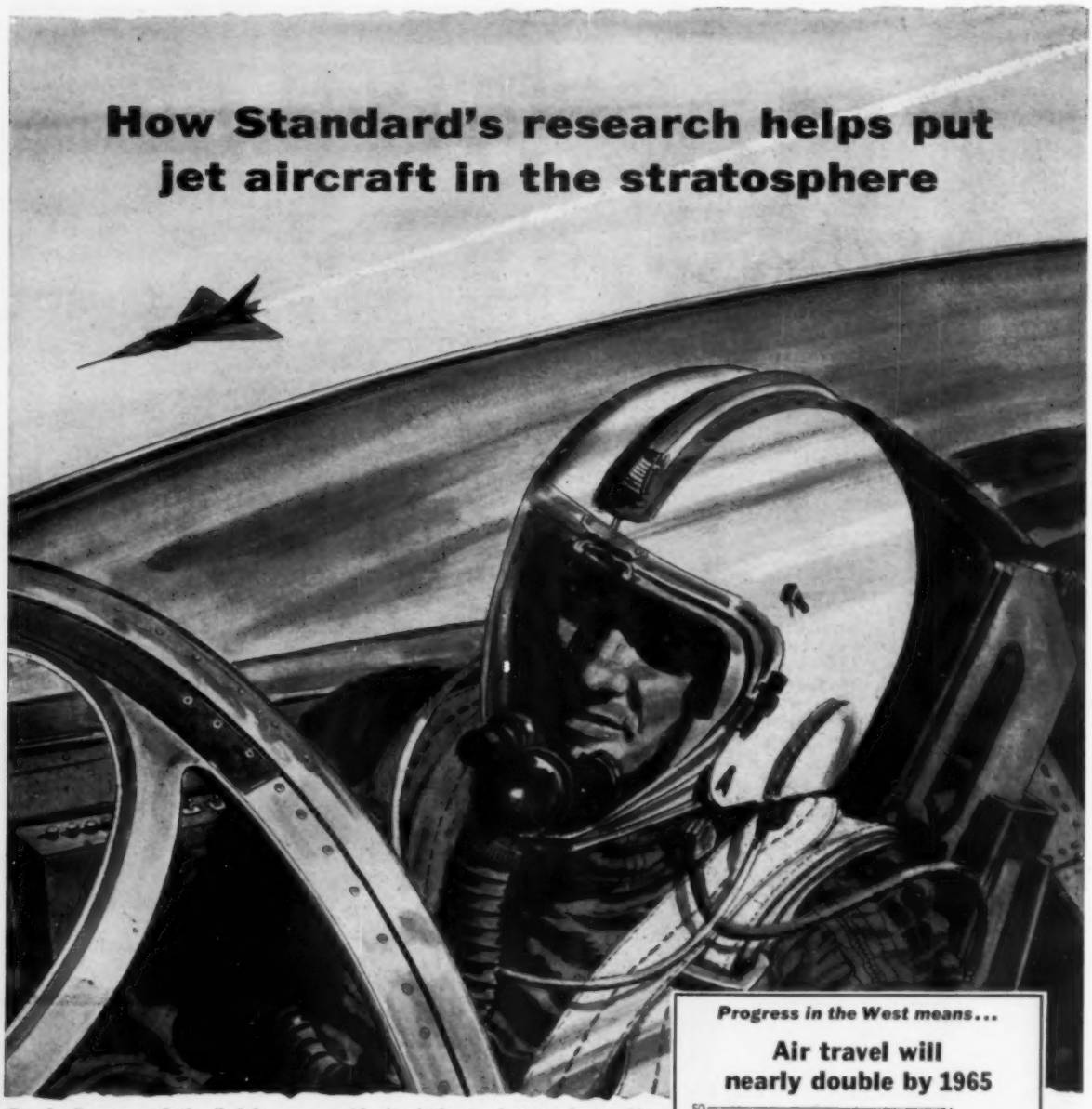
Sizes: ¾", 1" and 1¼" with cast iron or cast steel body. ¾" and 1" with malleable iron body.

FISHER GOVERNOR COMPANY
MARSHALLTOWN, IOWA
WOODSTOCK, ONTARIO

LEADS THE INDUSTRY IN RESEARCH FOR BETTER PRESSURE AND LIQUID LEVEL CONTROL

FISHER Since 1880

How Standard's research helps put jet aircraft in the stratosphere



Standard's new synthetic oils help conquer withering jet heat and stratospheric cold.

TEN MILES UP WHERE THE JETS FLY there's a world few men know. Temperatures from 70 to 100 below zero make ordinary lubricants thick and sluggish on controls that must respond instantly. But within jet engines, moving parts must be protected against withering heat up to 600° Fahrenheit.

Standard has "built" synthetic oils that stand up under both extremes. In less than five years these oils will be helping jet airliners whisk you safely to your destination, farther, faster, and more comfortably than ever before. We've been working toward that day since 1942 when Standard supplied the fuel used in the first jet flight in the United States.

Progress in the West means...

Air travel will nearly double by 1965

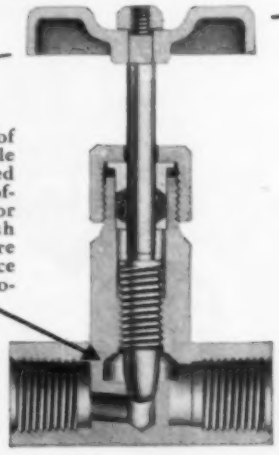
Jet airliners will carry twice as many passengers at twice the speed of conventional planes. Standard is getting ready now for 1965 when U.S. civilian and military demand for jet fuel will surpass aviation gas by more than 300,000 barrels a day.

STANDARD OIL COMPANY OF CALIFORNIA

plans ahead to serve you better

MAXIMUM WORKING PRESSURE
10,000 PSI
for water, oil or gas

- Body and stem guide extra heavy bar stock fused into one piece.
- Valve stem 416 stainless steel.
- Packing special one-piece "Marpak" moulded ring.
- Bodies marked in accordance with MSS regulations.



ONE PIECE

The stem guides of conventional needle valves are screwed into bodies—this often causes leakage or blow-outs. Marsh Needle Valves are fused into one-piece by exclusive "Conoweld" process.

The Ultimate in Needle Valves

Here is one of the crowning achievements of Marsh research, design, and manufacturing skill. It is the first needle throttling and shutoff valve to combine *all* of the qualities called for today in this highly critical and ever broadening field.

It is a valve that has strength and safety to spare . . . rated for pressures up to 10,000 psi—equally efficient in the lower ranges. A product of Marsh instrument-making and valve manufacturing experience, it combines instrument-like precision with the ruggedness that distinguishes all Marsh valve specialties.

The illustrations tell the story of new thinking; new standards. Body and stem-guide are machined from extra-heavy carbon steel bar stock. Still greater strength and rigidity are achieved by fusing the stem-guide into the body. The complete fusion of guide and body is accomplished by the exclusive Marsh "Conoweld" process.

There are two big advantages to this one-piece construction: (1) It eliminates the danger of unscrewing the valve from the body when opening—a frequent cause of leakage, even dangerous blow-outs (2) It permits perfect line-up of threads and seat. As a result, Marsh valves are easier to operate even at high pressures.

The precision-machined stem is 416 stainless steel. Stem threads are fine pitch for extra strength and fine, controlled regulation. Notable advancements are special "Marpak" one-piece, non-binding longer-lasting packing; deep thread chambers, keeping inlet and outlet piping away from ports and contributing excellent flow characteristics. Entire packing nut and packing gland are electro-zinc plated, preventing corrosion and giving the valve a handsome, plated exterior. The rugged malleable handle is finished in heavy baked enamel.

The new needle valve line includes globe and angle patterns with double female connections in sizes ⅛", ¼", ⅜", ½", ¾" and 1". Also globe and angle valves with male inlet and female outlet in sizes ¼" and ½". *Complete stock carried at our Skokie, Illinois factory and also at our branch plant in Houston, Texas.*

Write today for catalog giving complete details.

MARSH INSTRUMENT CO. *Sales Affiliate of Jas. P. Marsh Corporation*
Dept. M, Skokie, Ill. • **Marsh Instrument & Valve Co. (Canada) Ltd., 8407 103rd St., Edmonton, Alberta** • **Houston Branch Plant: 1121 Rothwell St., Sect. 15, Houston, Texas**

MARSH

"THE STANDARD OF ACCURACY"

...for straight right-angle cuts every time...the new

RIDGID

Wide-Roll Pipe Cutter

fast true pipe cuts on your power drive

Rolls are twice the usual width, double the bearing surface on pipe—sure straight start of cut . . . by hand or power drive—extra fast and easy. Pays you to see it before you buy your next cutter—at your Supply House.

No. 201, ⅛" to 1¼"
No. 202, ¼" to 2"

The Ridge Tool Company, Elyria, Ohio, U.S.A.

RIDGID
Work-Saver Pipe Tools

Trade Parade

W. G. Palmer, formerly chief engineer, has been named vice president for engineering of Mannix Gill Limited, Calgary, Alta. **Edward L. Jones,** formerly with C. F. Braun & Co., has joined the firm as chief engineer.

W. G. Palmer

E. L. Jones

W. E. Strittmatter

W. E. Strittmatter has been promoted to assistant treasurer of Mid-Continent Supply Company.

Mason-Neilan, Division of Worthington Corporation, Norwood, Massachusetts, have announced that **John W. Brown,** formerly manager at Seattle, Washington, has been appointed manager of the Pittsburgh District, replacing **A. Blair Powell,** recently promoted to general sales manager. **Thomas S. Robinson,** a sales engineer at the Skaneateles office since 1951, has been promoted to district manager at Seattle. The Delaware River Valley will now be served by a new District office at Wilmington, Delaware with **A. S. Chatfield** as manager.

Raymond H. Dunn has been appointed special petroleum representative at Dallas, Texas, for The Goodyear Tire & Rubber Company.

John W. Ostler has been named president and director of Canadian Meter Company, Ltd. He has been vice president and general manager of the company since 1955.

Willard T. Holmes has been appointed director of engineering and **Roy K. Stephens** has been named director of manufacturing of the Alectra Division, Consolidated Electrodynamics Corporation. Holmes previously was director of manufacturing for Alectra, and Stephens was manager of the division's printed wiring department.

Trade Parade

Grant C. Woodard has been promoted to general sales manager for the Cooper-Bessemer Corporation, Mount Vernon, Ohio. He will be responsible for the sale of all company products.

Paul A. Wallen has been appointed new area sales manager, covering the North Texas territory for The Charles Wheatley Company of Tulsa, Oklahoma.

Perry Brown, former plant works manager, has been elected a vice president of Johnston Pump Company.

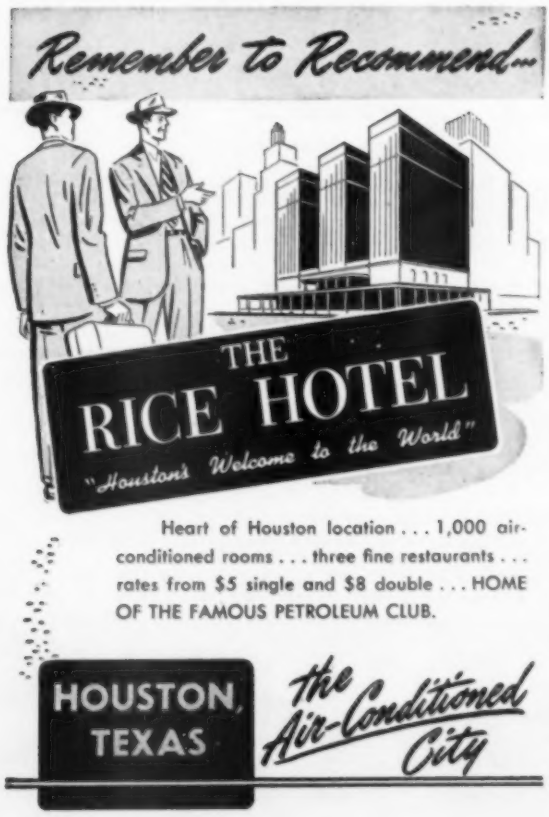
Appointment of **Edward N. Cooley** as vice president of ALCO Products, Inc. has been announced. He will be in charge of the Company's thermal products and petroleum industry equipment divisions with headquarters at Dunkirk, New York.

New promotions in area and district offices have been announced by Baroid Division, National Lead Company In Canada. **J. H. V. Matthews,** manager of Drilling Mud Products, Ltd., assumes the position of assistant area manager, Baroid of Canada, Ltd. He replaces **Ray R. Morris,** who has been appointed administrative assistant, drilling mud department, Houston, general office. **R. E. Nichols** is the newly appointed area engineer with headquarters in Calgary, Alberta, Canada. In the Louisiana Gulf Coast area, **Fred M. Hill Jr.,** former district superintendent, is the new administrative assistant, drilling mud department, New Orleans office and he was replaced as district superintendent of Southeast Louisiana by **Damon Bankston,** formerly sales representative in New Orleans.

Russell W. Wetjen has been appointed sales manager for petroleum, LP-gas and industrial meters of the Neptune Meter Company, New York City. He will supervise national sales of all Red Seal petroleum meters and Neptune industrial meters. He succeeds **Walter H. Sieger,** who has been elected president of Revere Corporation of America, a Neptune subsidiary.

American Iron & Machine Works Company Inc., of Oklahoma City has announced the following promotions; **Claude L. Griffin** has been named vice president and assistant to the president. **Varney S. Harlin** has been named vice president in charge of engineering and manufacturing. **W. R. Wheeler Jr.** has been named sales manager.

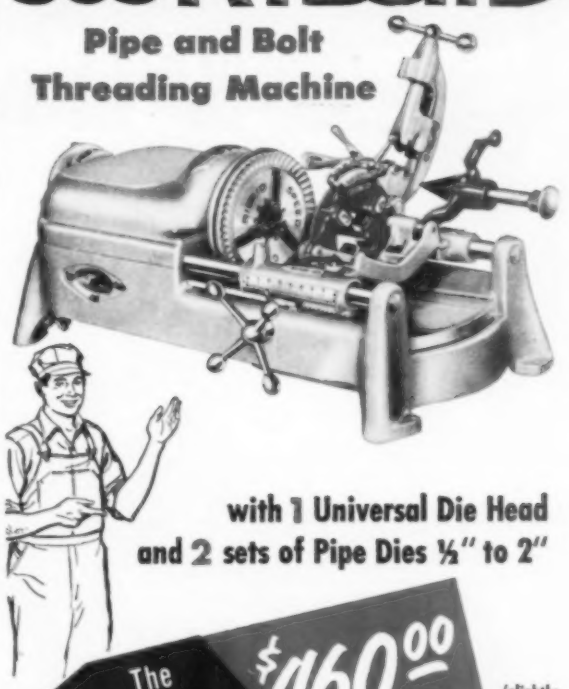
James B. Hartzog has been appointed manager of sales and service for S & R Tool and Supply Co., Houston, Texas. He formerly was with Ideco, Inc.



Heart of Houston location . . . 1,000 air-conditioned rooms . . . three fine restaurants . . . rates from $5 single and $8 double . . . HOME OF THE FAMOUS PETROLEUM CLUB.

HOUSTON, TEXAS *the Air-Conditioned City*

New
535 RIDGID
Pipe and Bolt
Threading Machine



with 1 Universal Die Head
and 2 sets of Pipe Dies ⅛" to 2"

The Complete Package $460.00 (slightly higher in Canada)

Your best buy
for fast easy pipe work . . . by power

Full range of pipe and bolt dies for universal head available

Complete machine, including Speed Chuck guaranteed to grip tight any pipe or conduit, forward, reverse . . . 1 universal quick-opening die head that adjusts to size right in machine, with 2 sets of dies, one for ⅛" and ¼", one for 1", 1¼", 1½", and 2". Roll type cut-off with self-centering full-floating cutter wheel . . . Five-Flute cone reamer, ⅛" to 2" . . . *Above 3 tools operate independently, swing up out of way when not in use, so pipe can be chucked from front* . . . Powerful 115/120 volt universal motor . . . All 500 and 500A die heads and accessories fit this 535 machine . . . See all the other RIDGID efficiency features of this remarkable 535 at your Supply House!

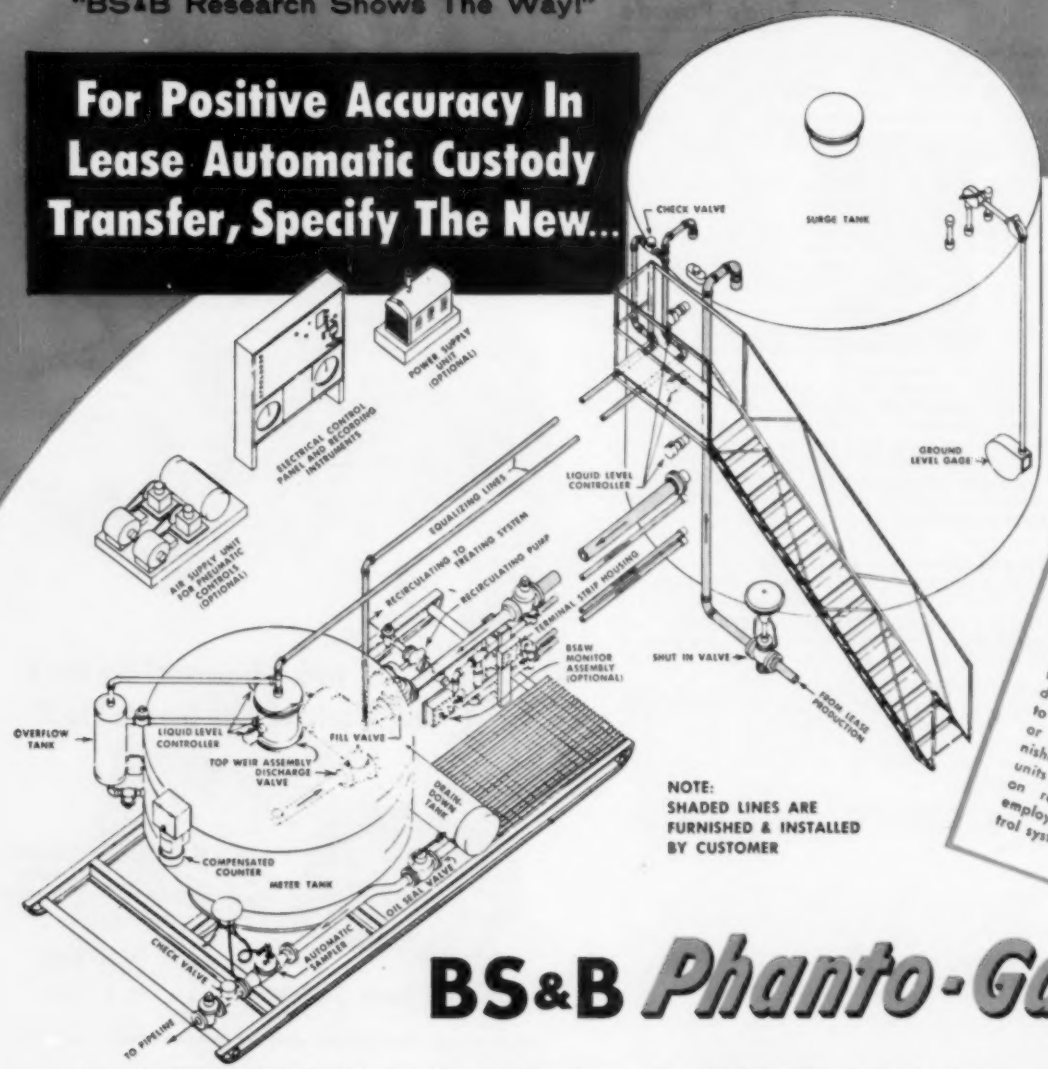
You can't afford to thread, cut and ream pipe by hand!

The Ridge Tool Company, Elyria, Ohio, U.S.A.

RIDGID
Work-Saver Pipe Tools

"BS&B Research Shows The Way!"

For Positive Accuracy In Lease Automatic Custody Transfer, Specify The New...



NOTE:
SHADED LINES ARE FURNISHED & INSTALLED BY CUSTOMER

PHANTO-GAGER VOLUMETRIC METER TANKS ...are available as standard in 25 and 50 bbl. sizes, but larger tanks capable of handling production of up to 1,000,000 bbls./day or over can be furnished. Smaller sized units are also available on request. All units employ standard control systems throughout.

BS&B *Phanto-Gager!*

The BS&B PHANTO-GAGER is that part of BS&B's new PHANTO-MATIC Lease System which automatically performs all the functions normally required to accomplish Lease Automatic Custody Transfer. It will:

1. Automatically measure and record temperature compensated oil volume in bbls.
2. Automatically measure (or automatically sample and subsequently determine) oil quality and contaminants.
3. Automatically run crude oil from a lease into connecting pipeline in accordance with predetermined schedules (if required) on an unattended basis.

The Extreme Accuracy of the PHANTO-GAGER is such that the purchaser or his agent is assured of receiving the *exact* amount of gross oil indicated by each recorded run because:

1. The upper weir on the meter tank and the degassing time when the oil is above the weir on filling are designed to give a positive high level gage.
2. The use of a valve between the meter and the drain down tank, plus a set drain down time, gives a positive low level gage.
3. The accuracy of measurement is not affected by the speed of valve action.
4. The meter tank and lines included in the calibrated volume are free of gas traps while filling, liquid traps while emptying.

Fail Safe Controls on The PHANTO-GAGER insure that no oil will be lost in case of power failure because:

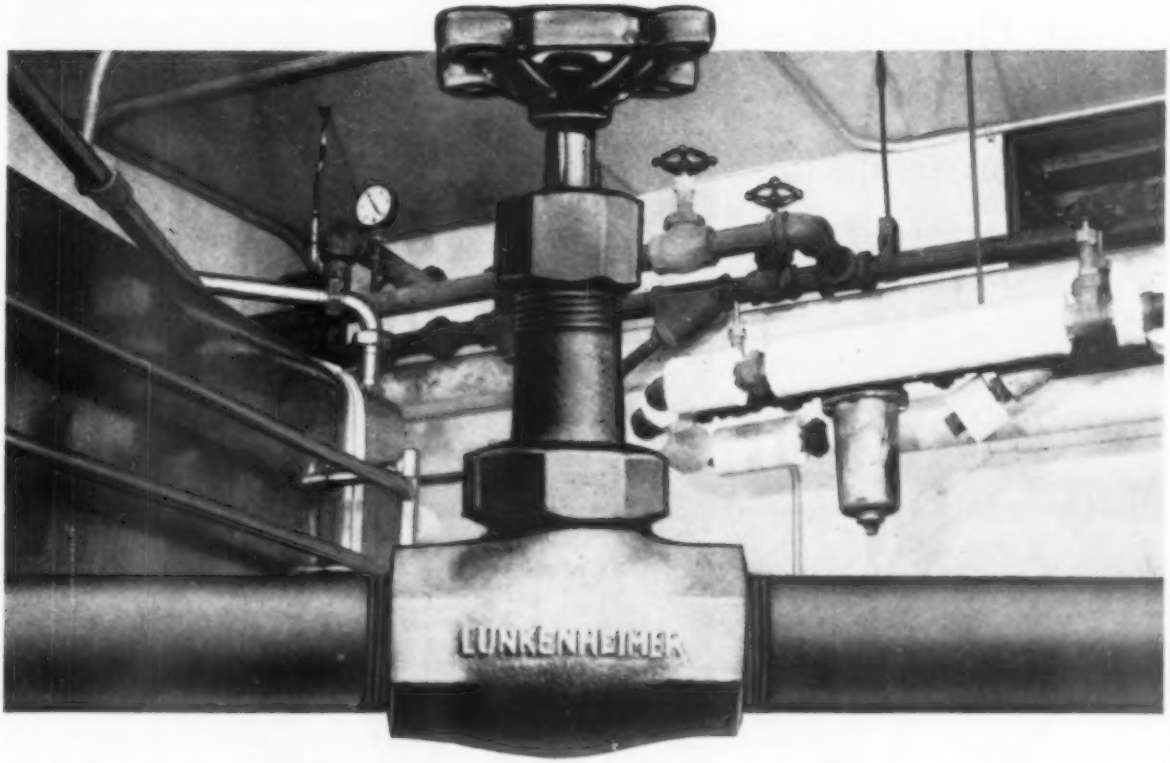
1. The fill and empty valves on the meter tank are electrically interlocked.
2. Oil cannot be introduced into the meter tank after the measuring cycle has started, nor can oil be removed from the meter tank (other than to the pipeline) after the top gage has been made and before the run is completed.
3. All electrical controls, motors, instruments and wiring within 150 ft. of the meter and surge tanks are explosion proof.

Together, the BS&B PHANTO-GAGER and the BS&B PHANTO-PUMPER (which automatically performs all lease operations ahead of the PHANTO-GAGER) make up the complete BS&B PHANTO-MATIC Lease System. This gives the lease operator full automation from the wellhead to the pipeline. Ask your BS&B Man to give you full details, or write to...

EFFICIENCY OVER 60 YEARS BS&B RELIABILITY
ANOTHER EXAMPLE OF PRODUCT LEADERSHIP

BLACK, SIVALLS & BRYSON, INC.
Oilfield Equipment Division, Dept. 1-C9.
P. O. Box 1714
Oklahoma City, Oklahoma

ONE ANSWER
to spiraling maintenance costs



LQ600—The Most Maintenance-Free Bronze Globe Valve Ever Developed!

The moment a maintenance man touches a wrench to a valve, its cost can double. You can't bring down that labor expense in many plants, but you can buy valves with an outstanding record of trouble-free service. At no time in history has valve quality been so important to your total plant expense. And quality has been a tradition for nearly a hundred years at The Lunkenheimer Company, Box 360, Annex Station, Cincinnati 14, Ohio.

See your cost-reducing Lunkenheimer distributor . . . or write for literature.

BRONZE • IRON • STEEL • PVC

The cost of a LUNKENHEIMER VALVE
Gets smaller...and smaller...and smaller...
with each passing year of dependable service

L-757-9

LUNKENHEIMER QUALITY

LUNKENHEIMER®
THE ONE *Great* NAME IN VALVES

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

Roebling Royal Blue Wire Rope goes to any length to prove its **high strength!**

Every inch of every foot of Royal Blue is stronger than any rope you've ever used on *any* job. This on-the-job tenacity helps to make it the most widely and readily accepted rope in Roebling's history. It is but one of Royal Blue qualities that makes for its long service life—on any job you choose. For full details on Roebling Royal Blue Wire Rope talk to your distributor or write to Wire Rope Division, John A. Roebling's Sons Corporation, Trenton 2, New Jersey, for your copy of "*Wire Rope Recommendations and Catalog*."

ROEBLING

Branch Offices in Principal Cities—Subsidiary of The Colorado Fuel and Iron Corporation

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

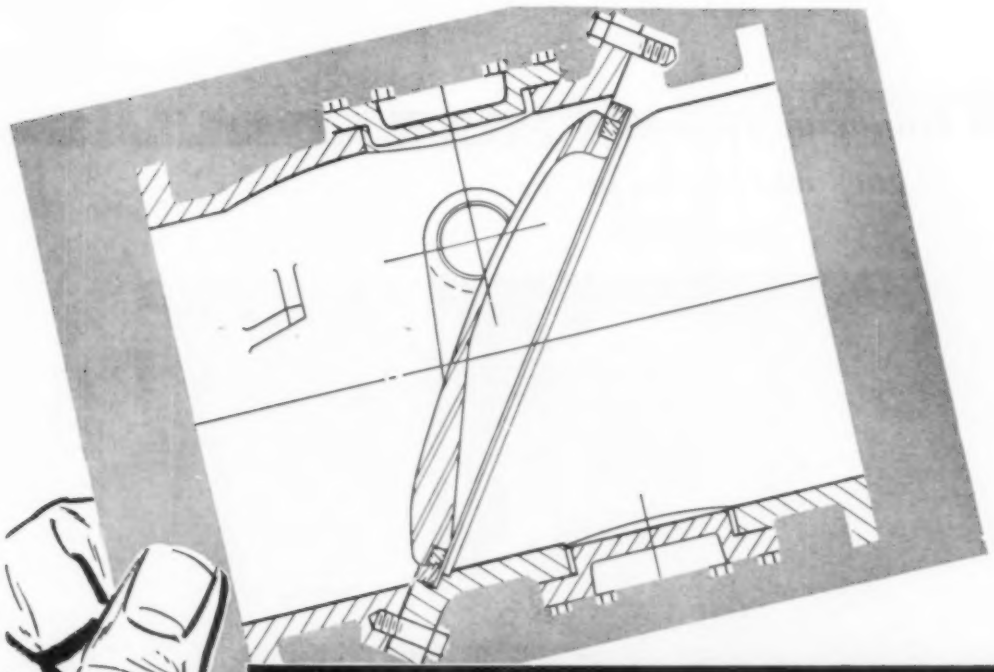


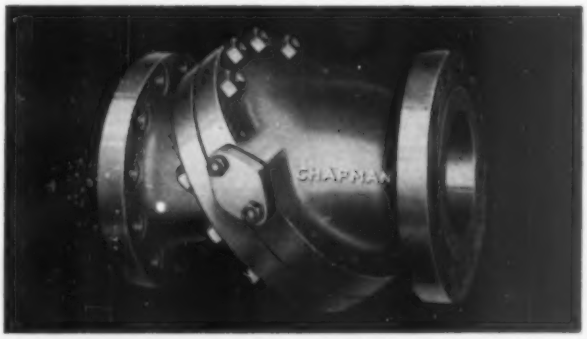
Diagram for quick, quiet, low-cost valve operation

Here's the picture . . . a cross section showing the working principles of the Chapman Tilting Disc Check Valve. It makes sense. It's a clear-cut diagram of a way to save dollars.

Notice the body design — plenty of room allowed to eliminate flow resistance, and the balanced "Airfoil" disc supported on a pivot. When the flow is on, disc opens wide enough to meet the demands of the flow. When the flow is off, disc drops quickly to a firm, tight seat. This is not only quick operation . . . it's quiet operation. There's no flutter. No banging. No slamming. No scraping of disc and seat. All this, of course, means low-cost operation. There's nothing to cause wear and tear or damage to valve or system. Your maintenance costs are low even under severe conditions.

CHAPMAN
Tilting Disc Check Valve

For best results in handling fluids or gases at the lowest cost, specify Chapman Tilting Disc Check Valves. They cover a wide range of pressures and are available in iron or steel. You'll find them all with complete data in our Catalog 30-A. Write for your copy, now.



The CHAPMAN
Valve Manufacturing Co.
INDIAN ORCHARD, MASSACHUSETTS

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Oil Financing from the **FIRST** *in* **DALLAS**
goes where you go . . .

Mr. John A. McGuire, President, Three States Natural Gas Company, is a longtime customer of the FIRST in DALLAS. Large producers of natural gas, Three States, with headquarters in Dallas, centers its production in Carbon, Emery and Sanpete Counties, Utah.

Specialized experience, organization, and resources to help you with practically any kind of need for "working money".

FIRST NATIONAL BANK IN DALLAS

Member Federal Deposit Insurance Corporation

put FIRST financing in your own oil future

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

a century of service

In September, 1857, Hieronymus Mueller opened a one-man gun and repair shop in Decatur, Illinois. Mueller's inventive genius and insistence on perfection gained many customers; and the shop prospered.

In 1871, Mueller was appointed city plumber. At that time, a new water service was connected to the main by drilling a hole, almost through the main, and then inserting a drive stop into the partially drilled hole with a blow of a sledge. Usually the plumber was drenched, the trench flooded. It was often necessary to shut off the main, interrupting service to other customers while the connection was repaired.

Mueller was quick to recognize the need for a better method of making service connections and, in 1872, invented and patented the original water main pressure tapping machine, which drilled a hole in the main, tapped the hole and inserted the stop — all without interrupting service and without flow of water into the ditch. A vital need of the expanding water industry had been answered — the first of many such answers through a century of service.

MUELLER® today . . .

Mueller Co. looks to the future as it meets the needs of today. Mueller design and research engineers are already working on tomorrow's problems of the water, gas and oil industries. Five factories, equipped with precision machines, manned by skilled workers, manufacture quality products.

Upon the firm foundation established 100 years ago, Mueller builds for tomorrow and a second century of service to the vital water, gas and oil industries.

MUELLER CO. 100th YEAR SERVING the Water and Gas Industries QUALITY

Since 1857

MUELLER CO.

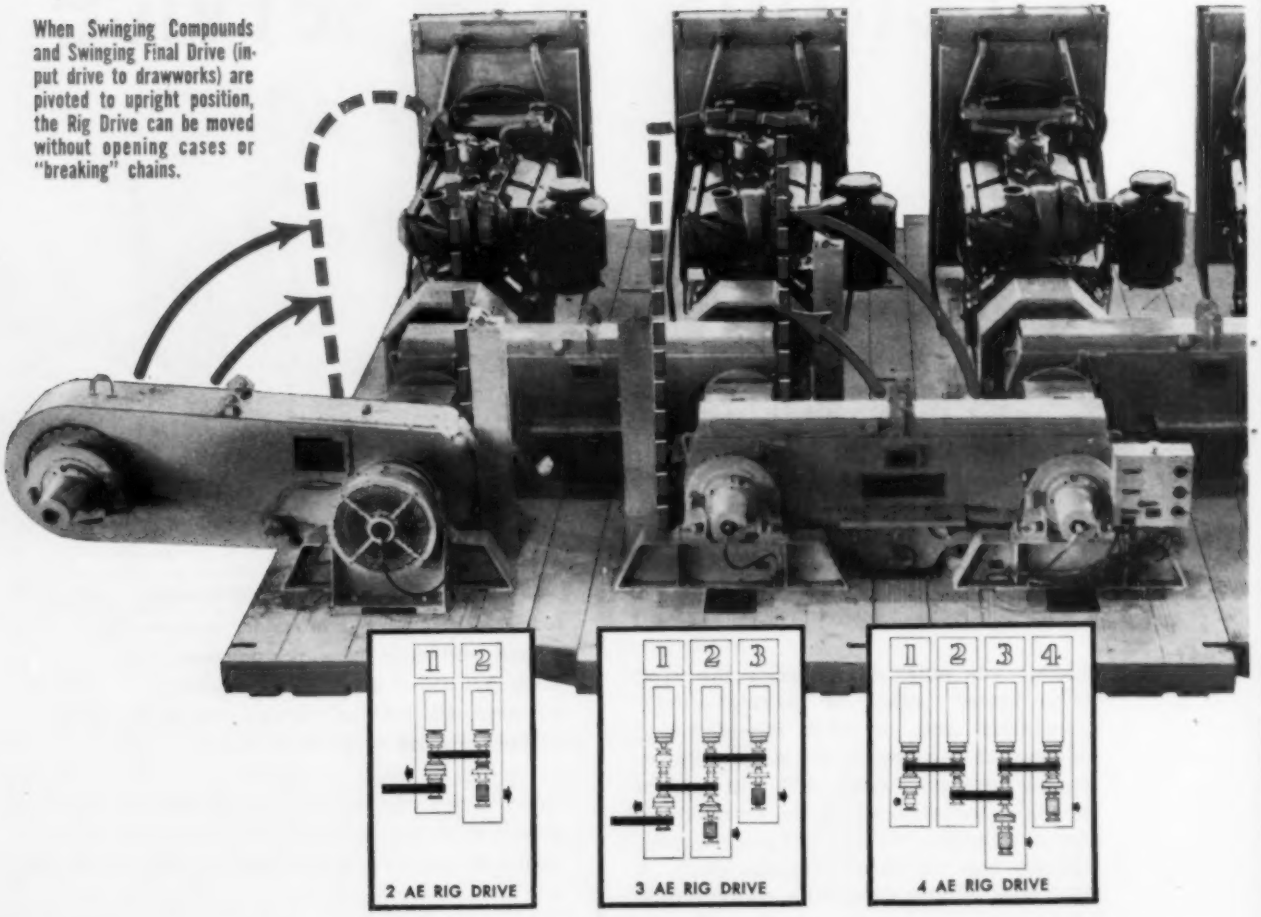
DECATUR, ILL.

Factories at: Decatur, Chattanooga, Los Angeles.
In Canada: Mueller, Limited, Sarnia, Ontario

. . . Proved by 10 YEARS

Mid-Continent

When Swinging Compounds and Swinging Final Drive (input drive to drawworks) are pivoted to upright position, the Rig Drive can be moved without opening cases or "breaking" chains.



Compounds swing for easy moving . . . quick rig-up!

Exclusive Swinging Compounds on all Mid-Continent AE Rig Drives simplify the addition of engines. All compound case assemblies are identical whether two-, three-, or four-engine Rig Drive. The Swinging feature makes possible moves without opening compound cases, draining oil, or "breaking" chains. Simply by pivoting Swinging Compounds to a vertical locked position, the units are ready to move to the next location. Swinging Final Drive, specified for many installations, adds still more to the versatility of this superior Rig Drive.

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

World-Wide Experience

*Swinging Compound**

rig drive for any engine

In 10 years of world-wide service, the Mid-Continent *Swinging Compound has proved its versatility and superiority for practical multiple power assemblies. The Mid-Continent Rig Drive is readily adaptable to most engine-drawworks combinations. Its exclusive Swinging Compounds speed up moves and reduce rig-up time. The Mid-Continent rig drive has a field-proved reputation for long service without overhaul. More than 100 of these outstanding rig drives have been specified by oil companies and drilling contractors for their world-wide drilling operations. Whatever your rig drive requirements, Mid-Continent's engineering staff is ready to assist you. Call your nearest Mid-Continent representative today.**

Since 1947, more than 100 Mid-Continent Rig Drives have been specified for drilling world-wide.

1947

1948

1951

1952

1955

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Export Division: 45 Rockefeller Plaza, New York 20, N. Y. CABLE ADDRESS: MIDCUMPORT NYK

MID-CONTINENT Supply Company

MID-CONTINENT BLDG. FORT WORTH, TEXAS

PESA

THE WORLD'S LARGEST INDEPENDENT OIL FIELD SUPPLY COMPANY

A crude oil pipeline pumping station on the Gulf Coast of Texas. Here four E-M Sil-Clad Motors are on outdoor duty. Two are rated 500 hp and two 600 hp, at 3600 rpm.

WHERE'S THERE A MOTOR

that'll take more than the weather can dish out?

Exposure to scorching sun, sticky humidity, drenching rain, and corrosive salt air doesn't affect the operation of the four E-M Sil-Clad Weather-Protected Motors pictured above. They continue to drive crude oil pumps at a Texas Gulf Coast pipeline station with no more attention than routine bearing inspections.

Here are the maintenance-saving Sil-Clad features:

CORROSION RESISTANT INSIDE AND OUT. All exposed metal parts are protected with baked-on silicone. Fans, baffles and screens are stainless steel. Weather-protected construction eliminates internally corrosive "breathing."

INSIDE STAYS CLEAN. High intake air lift thru baffles at low velocity drops out foreign matter. Blow-thru passages by-pass gusts.

AGE-DEFYING INSULATION. A baked-on silicone "envelope" insulates Sil-Clad Motor coils. The coils repel moisture and salt air, resist high ambients.

EASY TO GET AT. Bearing inspection thru ports and hand holes. Hood lifts off for complete access.

Sil-Clad Motors can give big savings in refineries and on off-shore rigs, too. When you're considering a motor for outdoor duty in damp or corrosive atmospheres, ask your local E-M Sales Engineer about Sil-Clad Motors. Our factory will also be glad to send you a copy of Publication 209 which tells more about E-M silicone protected motors.

E-M

1300-TPA-2148

ELECTRIC MACHINERY MFG. COMPANY

Minneapolis 13, Minnesota

Specialists in making motors do
EXACTLY WHAT YOU WANT THEM TO

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

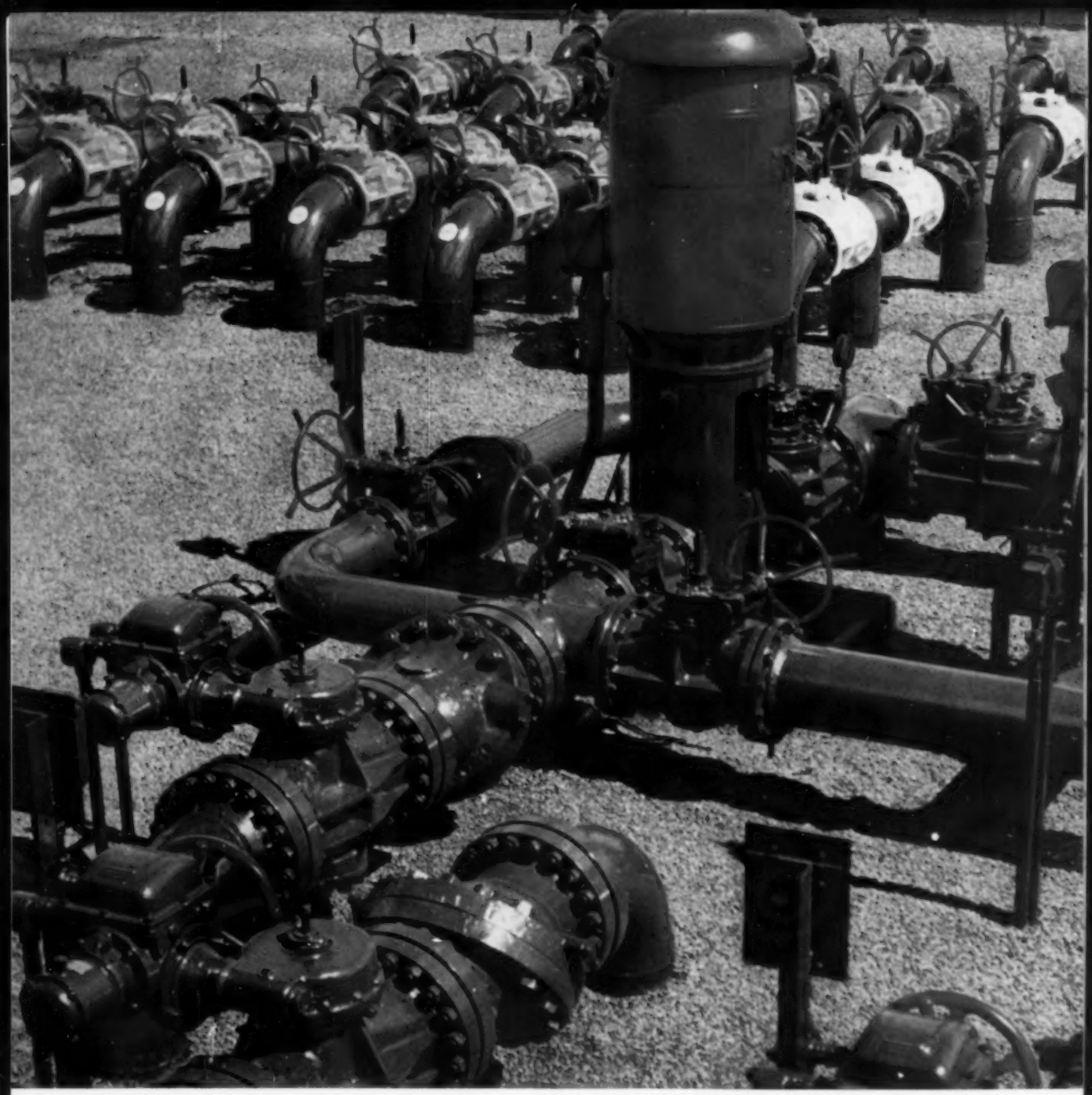
TROUBLE FREE... You can't buy a more trouble-free, leak-proof valve than Rockwell-Nordstrom; that has been proven over the last 40 years. The basic reasons: a durable, *pressurized lubricant* seal holds the lightest gases or heaviest slurries bottle tight. And, *lubricant protection* eliminates metal-to-metal wear —prevents valve failure, keeps maintenance costs lower than any other valve.

Rockwell-Nordstrom, the world's most complete line of lubricated plug valves, will give you better flow control at lower cost everywhere you use them. And they cost no more to buy, often less, than ordinary valves. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

Available at leading suppliers . . . everywhere.

ROCKWELL-
Nordstrom
VALVES

Lubricant Sealed For Positive Shut-Off



RUGGED Rockwell-Nordstrom valves *stay* trouble-free on pump and compressor lines. Why? Their firmly seated, lubricated plug prevents seat failures that are common to ordinary valves on high pressure or pulsating flow. And even on hard to handle services, shut-off is always positive because a tough film of lubricant forms an instantly replaceable, double seal against leakage.

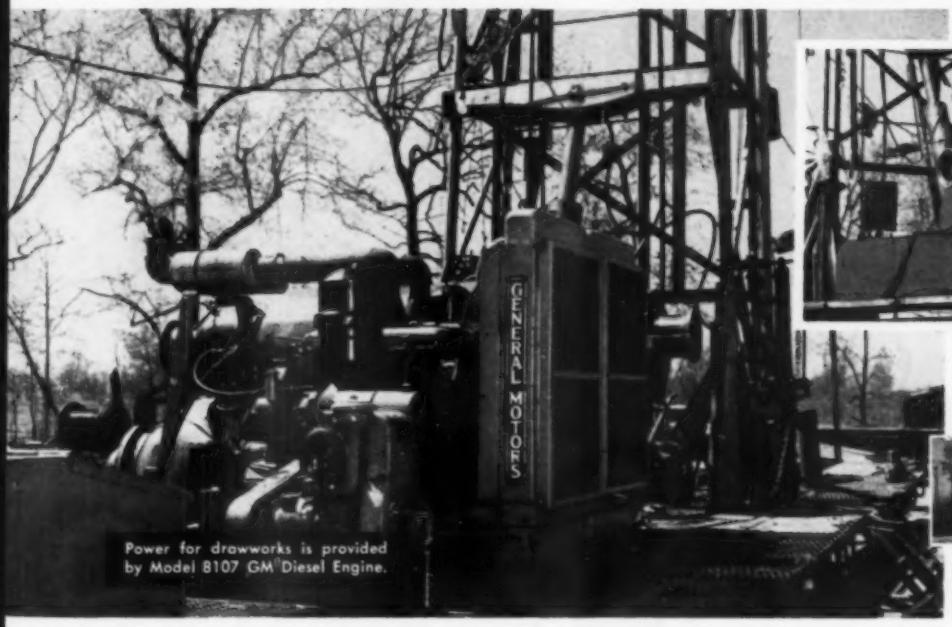
Rockwell-Nordstrom is the original and world's most complete line of lubricated plug valves and lubricated plug valve accessories. They cost no more to buy, often less, than ordinary valves and they'll save money, give better performance everywhere you use them. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

Available at leading suppliers . . . everywhere.

ROCKWELL-
Nordstrom
VALVES

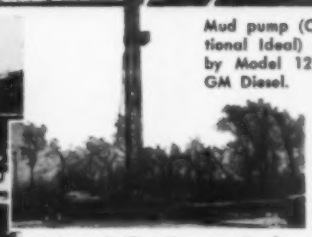
Lubricant Sealed For Positive Shut-Off

DEPENDABLE POWER



Power for drawworks is provided by Model 8107 GM Diesel Engine.

Mud pump (C-150-B National Ideal) is powered by Model 12103 Model GM Diesel.



Johnson Drilling Company Truck-mounted portable rig in the Tyler area.

"OPERATED MORE THAN TWO YEARS WITH NO MAJOR REPAIRS."

That's how T. J. Johnson of Tyler, Texas, head of the Johnson Drilling Company, describes the new application of GM Diesel engines that powers the hard-working portable rig shown above. A Model 8107 GM Diesel Engine provides power for the Spencer-Harris Drawworks and a Model 12103 GM Diesel Engine operates the mud pump. This well, in the Tyler area, was drilled to 6300 feet with 3½-inch drill pipe and eight drill collars.

Stewart & Stevenson — Industrial Power & Supply Co. parts and service? "Most satisfactory," says Mr. Johnson.

And here are this contractor's ratings of other important factors:
Performance — "Superior."

Dependability — "Engines are ready to deliver at any time called upon."

Power — "The two-cycle system gives fast, positive power at all times."

Dependable and economical power — the best in service — those are the characteristics of Stewart & Stevenson Services, Inc., and their dependable dealers, which have made the company the world's largest distributor of diesel engines.

Drilling is highly competitive today. The difference may be in your power and Stewart & Stevenson has the difference.

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We're proud of our record in meeting every power need for the nation's leading drilling contractors

THE WORLD'S LARGEST DISTRIBUTOR OF DIESEL ENGINES

Why Rib-Tops are *first* in the oil fields of the world

The four engineering developments shown at the right have made Rib-Top first choice for mud pump operation with drillers around the world.

Yet Rib-Tops cost no more than ordinary belts of comparable ratings.

For fewer V-belt replacements and lower cost on mud pump drives, always specify Rib-Top. Both Standard and Super Rib-Top are available at your nearby oil field supply house.

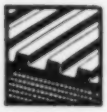
Put Super Rib-Top on your toughest drives.

With 40% more horsepower capacity, Super Rib-Top easily handles drive overloads. Fewer belts and narrower sheaves solve space and weight problems.

No other V-Belt has ALL these advantages

1. **Tougher, more resilient cords** are able to absorb the severe pulsations of mud pumps; easily handle peak loads.

2. **Concave Sidewalls** (U.S. Pat. 1813698) Concave sides (Fig. 1) increase belt life. As belt bends, concave sidewalls become straight, making uniform contact with sheave groove (Fig. 1-A). Uniform contact means less wear on sides of belt . . . far longer belt life.



3. **Stabilizing ribbed tops** (U. S. Pat. No. 2548135) are exclusive with Gates. They dampen vibration, protect top of belt from damage, keep belt running smoothly over idler-equipped mud pump drives with no side whip.

4. **Flex-Weave Cover** (U. S. Pat. 2519590) A Gates exclusive: provides greater flexibility with far less stress on fabric. Cover wears longer . . . increases belt life . . . more power available to driven machine.

Gates® *World's Largest Maker of V-Belts.*

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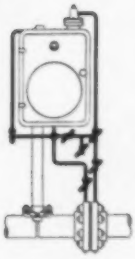
Gates Rib-Top Vulco Rope

DEVELOPED ESPECIALLY FOR MUD PUMP DRIVES

For corrosive field service...

AMERICAN® Needle Valves



Teflon-packed, forged steel American® Needle Valves stand up in the toughest meter manifold jobs and other corrosive field services without gland leaks. Stainless or carbon steel precision machined valve bodies are specially suited for welding. Stainless steel centerless-ground valve stems are designed so that the valve can be repacked under pressure.

Standard valves design rated for pressures to 5,000 psi at 70°F. For pressures to 10,000 psi, upon request, valves are hydrostatically tested and individually inspected. Valves are furnished with graphite-impregnated asbestos packing for temperatures above 450°F.

Angle or straight patterns —screwed or union bonnets.

Consult your American Meter representative for full details.

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ONLY DeZurik MAKES THE *Easy-Operating* PLUG VALVE WITH ECCENTRIC ACTION!

DeZurik gas operated valves on water filters at the Mid-Burbank Water Flood Project operated by Phillips Petroleum Company, Osage County, Oklahoma.

Whether it's dead-tight shut-off you want in a valve . . . or easy operation . . . or freedom from constant maintenance, you'll find the answer in DeZurik Plug Valves. *Exclusive* eccentric action guarantees easy, trouble-free operation; resilient plug-facing assures leak-free closure — every time! On any line! Even when automatically operated.

DeZurik Valves are available in sizes from ½" thru 20", in a full range of metals, and for manual, pneumatic, hydraulic or electric operation. Representatives in all principal cities; or, for more details on DeZurik Plug Valves, write

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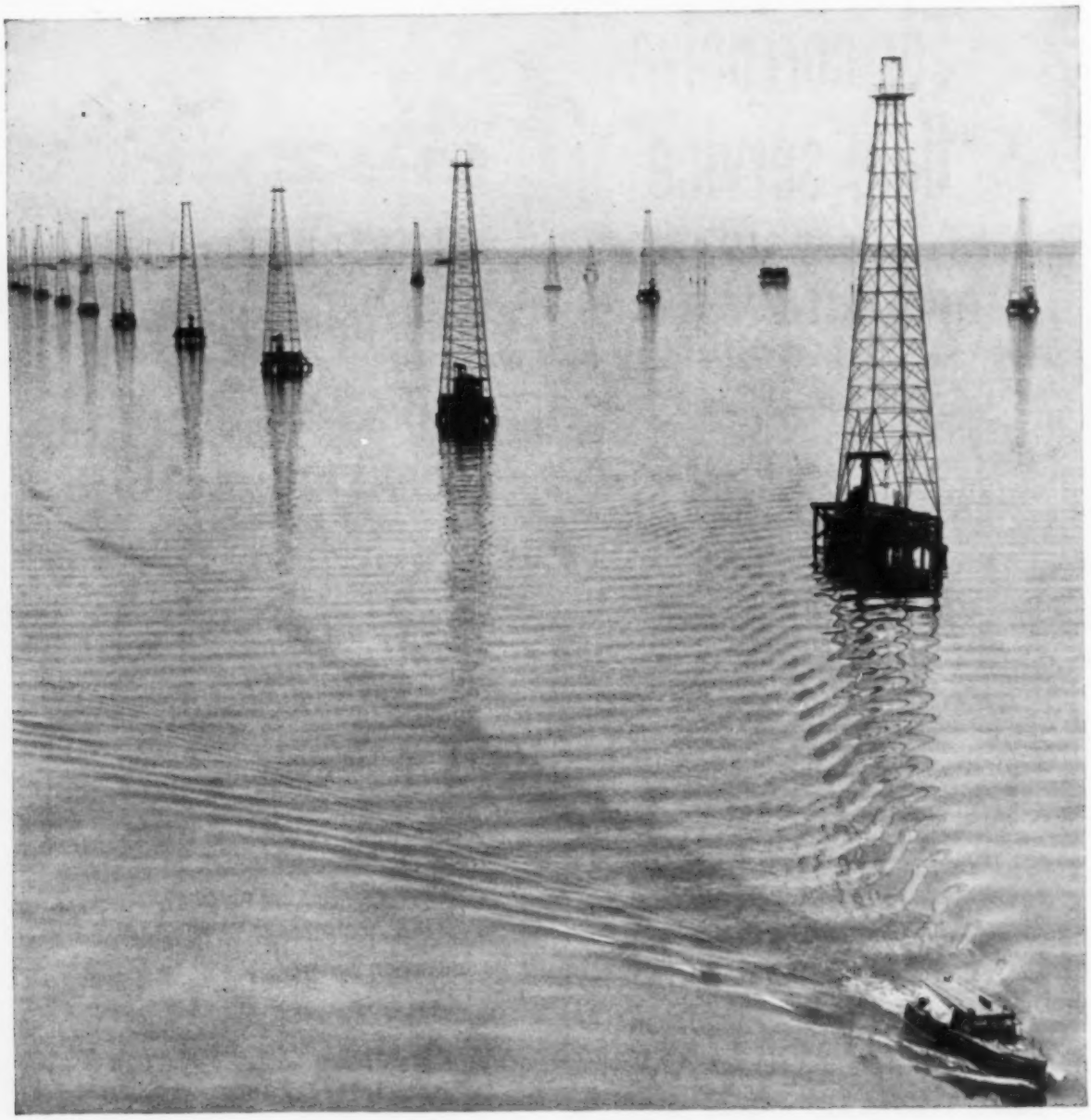
SARTELL, MINNESOTA



"A vital need for an expanding world economy is that kind of integrity in governments which encourages confidence... governments that are consistent, reliable, and responsive, not only in their dealings with their own citizens, but in dealings with each other and with each other's citizens."

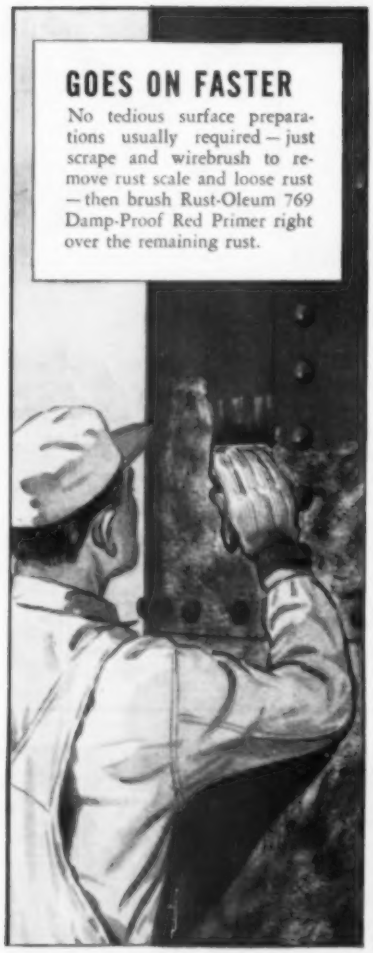
—Eugene Holman, Chairman of the Board, Standard Oil Company (New Jersey)

ESSO 75 YEARS

producing energy for an abundant life

STANDARD OIL COMPANY (NEW JERSEY)
AND AFFILIATED COMPANIES

Three Rust-Oleum DIFFERENCES that save you time, money and metal!



GOES ON FASTER

No tedious surface preparations usually required — just scrape and wirebrush to remove rust scale and loose rust — then brush Rust-Oleum 769 Damp-Proof Red Primer right over the remaining rust.

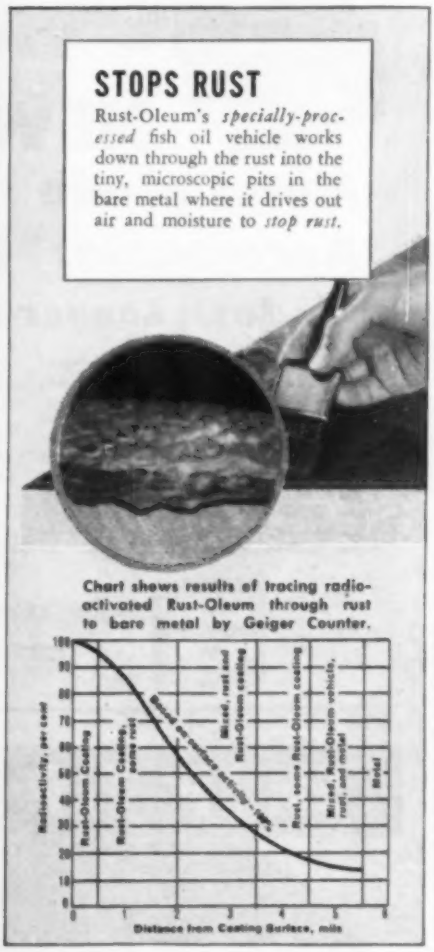


Chart shows results of tracing radio-activated Rust-Oleum through rust to bare metal by Geiger Counter.
Radioactivity, per cent
Rust-Oleum Coating
Rust-Oleum Coating, some rust
Mixed, rust and Rust-Oleum coating
Rust, some Rust-Oleum coating
Mixed, Rust-Oleum vehicle, rust, and metal
Metal
Distance from Coating Surface, mils

STOPS RUST

Rust-Oleum's *specially-processed* fish oil vehicle works down through the rust into the tiny, microscopic pits in the bare metal where it drives out air and moisture to *stop rust.*

LASTS LONGER

Applied over rust, Rust-Oleum lasts longer for the *over-the-years protection* you need. It resists sun, salt water, salt air, fumes, heat, humidity, moisture, weathering.

These are just a few of many important *differences* that separate Rust-Oleum from ordinary coatings. When you consider that Rust-Oleum covers approximately *30% more area,* depending upon surface condition and porosity . . . and the fact that Rust-Oleum finish coatings, with the same fish oil vehicle, are available in nearly every color for *double protection* . . . it's just good, common sense to use Rust-Oleum. Prompt delivery from Industrial Distributor stocks. Write for illustrated literature with color charts.

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Rust-Oleum is distinctive as your own fingerprint. Accept no substitute.

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Dine in the splendid old world setting of a grand dining room. The menu is varied, the service unexcelled.

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One of the brightest of the city's supper clubs. Dancing nightly from 9:00 p.m.
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Pause — in the relaxing, informal atmosphere of the gayly decorated Patio. It's a Cleveland habit to say — "Meet me at the Patio."

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Service is brisk and decor cheerful in the modern, air-conditioned coffee shop. Enjoy a tasty sandwich or a moderately priced meal.

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NEW Metal Blade Aeromaster* Fan

AEROMASTER fans 54" to 22' for cooling towers and radiator-type coolers.

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AEROMASTER fans are efficient because they embody advanced aerodynamic principles. True airfoil blade sections give maximum air delivery.

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AEROMASTER fans are durable because they are made from corrosion resisting, silicon-magnesium, aluminum alloys with high tensile strength, fine grain structure and increased endurance limit.

For more details write to KOPPERS COMPANY, INC., Aeromaster Fan Dept., 6709 Scott Street, Baltimore 3, Md.

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Ask your jobber—or write for DURA HOOK Bulletin No. PEDH covering sizes and prices.

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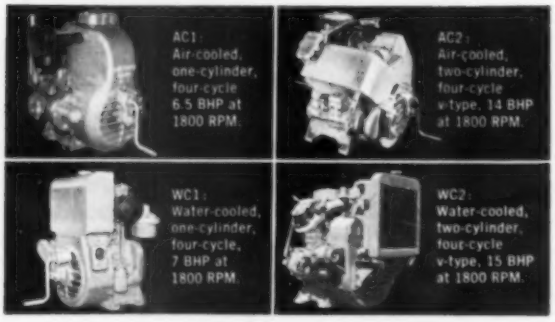
AMERICAN MARC Inc. dominates the field of lightweight, low-horsepower Diesels by building its diversified line from the "Big Four" basic models illustrated here. Purchase and maintenance of engines and parts are simplified by the use of these compact and rugged prime movers.



AC1: Air-cooled, one-cylinder, four-cycle 6.5 BHP at 1800 RPM.

AC2: Air-cooled, two-cylinder, four-cycle v-type, 14 BHP at 1800 RPM.

WC1: Water-cooled, one-cylinder, four-cycle, 7 BHP at 1800 RPM.

WC2: Water-cooled, two-cylinder, four-cycle v-type, 15 BHP at 1800 RPM.

AMERICAN MARC also manufactures Diesel generating plants from 3 to 10 KW (AC or DC, and industrial three-phase), Diesel pumping units from 48 to 1700 GPM, marine propulsion, refrigeration units and power-packages for other services. American MARC can adapt any of its Big 4 engines to fit every job requiring from 5 to 20 BHP.

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BRAKESOL is being used all over the world today and is accepted as one of the most effective methods of treating and controlling the paraffin problem.

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BRAKESOL is non-corrosive and will not harm production or refinery equipment.

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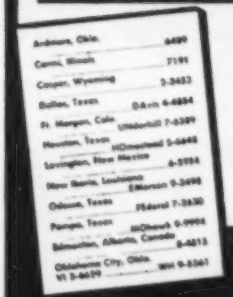

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Increased Revenue!

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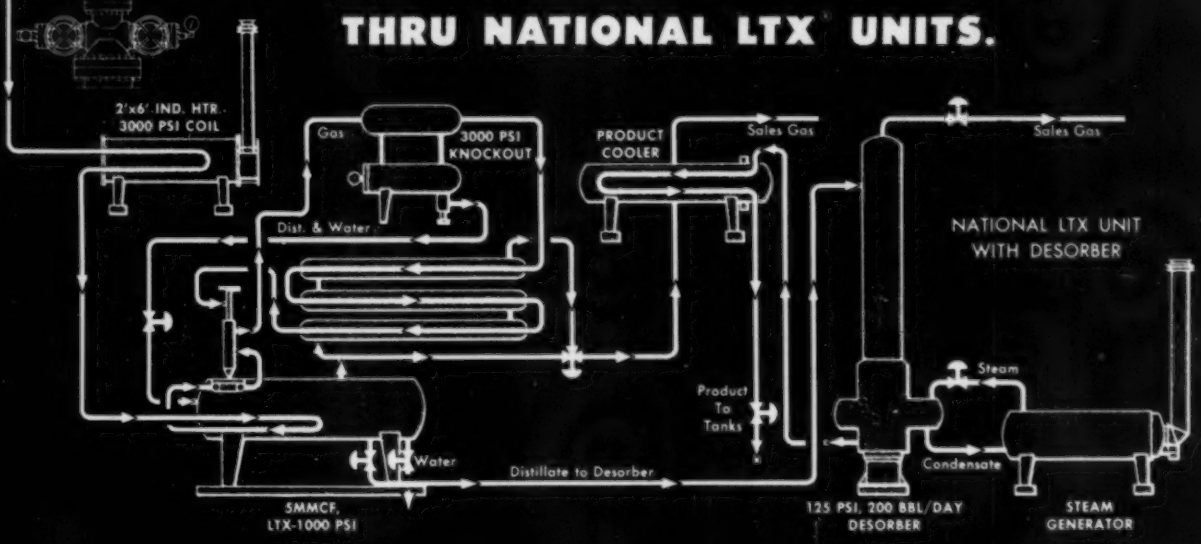

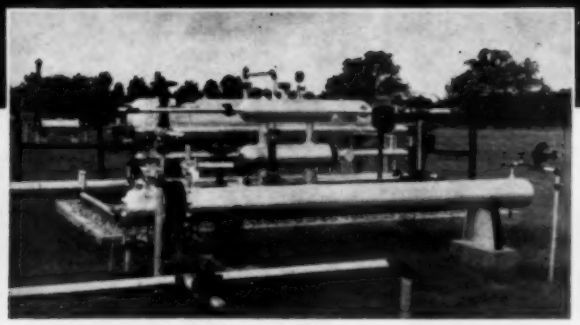

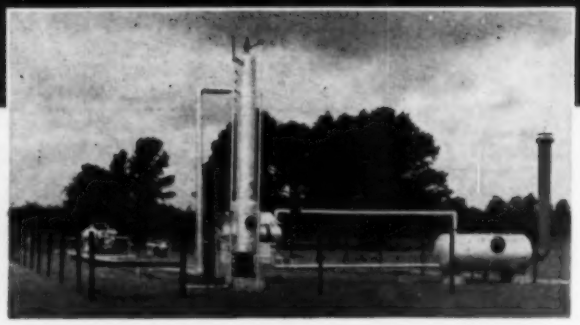

Installation of a National LTX Unit with desorber on this gas distillate well near Shreveport, Louisiana, INCREASED the recovery 14 barrels of stock tank liquid per MMCF of sales gas produced.* The well originally tested 70 barrels per MMCF with conventional separation equipment and increased to 84 barrels per MMCF of sales gas produced after the installation of LTX equipment. The LTX unit operates at approximately 300 psi and 5°F. Flowing pressure is approximately 2500 psi.

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**For a more finite economic evaluation, the differences in recovery should be based on the unit of well effluent. This is not data that can easily be observed in the field for it requires calculations based on the wellstream hydrocarbon composition. Such determinations are often valuable.*

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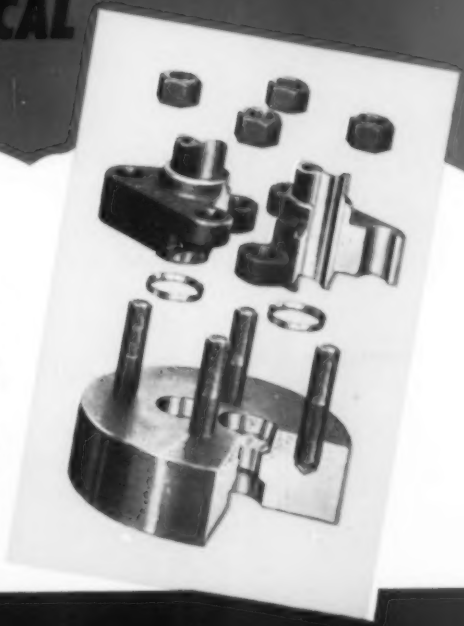
DELTA FLANGES

Make O-C-T Dual String Trees *STRONGER, LEAKPROOF, ECONOMICAL*



The unique design of O-C-T Delta Flanges has materially increased the strength and maintenance-free life of dual string trees.

Many dual string trees tend to "Y" out under pressure if they have unbalanced flanges. This stress aggravates leakage problems and often necessitates expensive extra bracing to hold the two strings together.

O-C-T Delta Flanges have solved this problem. The balanced design — plus the Laurent Seal Rings that keep pressure area at a minimum — makes possible a perfectly balanced, leak-free tree with no tendency to "Y" out.

Ask your O-C-T Representative about the many advantages of Delta Flanges or write for complete information and literature.

Best thing that ever happened to a dual string tree

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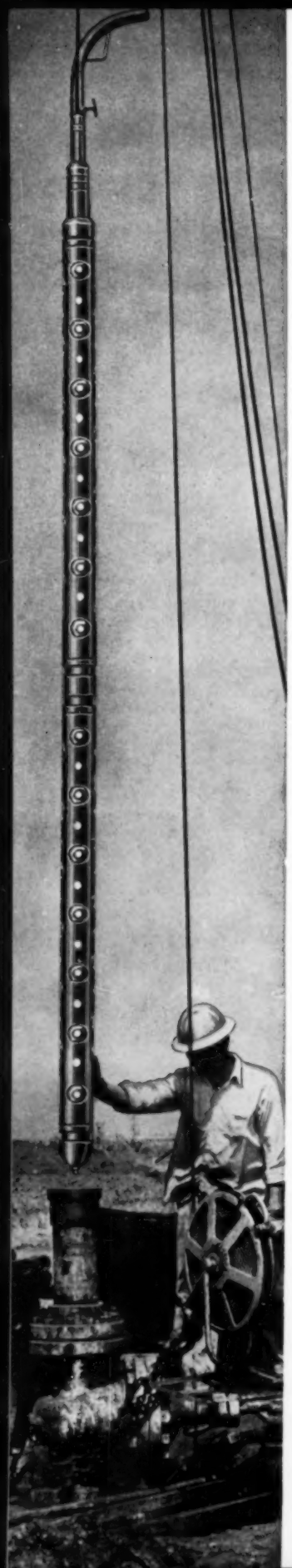


Save rig time!

shoot more shots
on ONE run with

LANE-WELLS
E-GUN

Yes, you can save rig time by shooting as many as 75 shots on a single run with the Lane-Wells E-Gun – the same hard-hitting E-Gun that gets the deepest penetration of all bullet guns. This means most of your perforating jobs can be completed with only one run. Even large jobs requiring hundreds of shots can be completed up to three times faster.

For bullet, shaped-charge, open-hole, thru-tubing and all perforating jobs call your Lane-Wells man about the complete perforating service.

Tomorrow's Tools-Today!

FOR INFORMATION WRITE:
P. O. BOX 1664, HOUSTON 1, TEXAS

LANE-WELLS CANADIAN CO. IN CANADA

Of Things To Come . . . In Oil

DRILLING ACTIVITY TO PICK UP if all "signs" can be interpreted right. Second quarter completions were greater than first quarter this year indicating an upward trend; U. S. Bureau of Mines predicts greater demand for domestic crude in view of Eisenhower's recommended limitation on imports. The picture could well hinge upon how close imports stay within suggested "boundaries."

OFFSHORE ACTIVITY TO CONTINUE HIGH, but don't look for another boom like the one last year. Drilling is increasing very slightly and is leveling off. Costs continue to climb; offshore production problems far from being solved economically. However, reserves are being proved up; and the offshore industry continues to plug along at a high spending rate.

THE PICTURE ABROAD LOOKS BRIGHT, if trends so far this year are any indication. New and big concessions have been let in most of the active areas over the globe . . . and, many U. S. firms are in on the ground floor. Foreign production isn't limited like domestic production, and more and more large and small operators as well as contractors find a keen interest abroad. Canada and South America will receive continued high activity for the remainder of 1957.

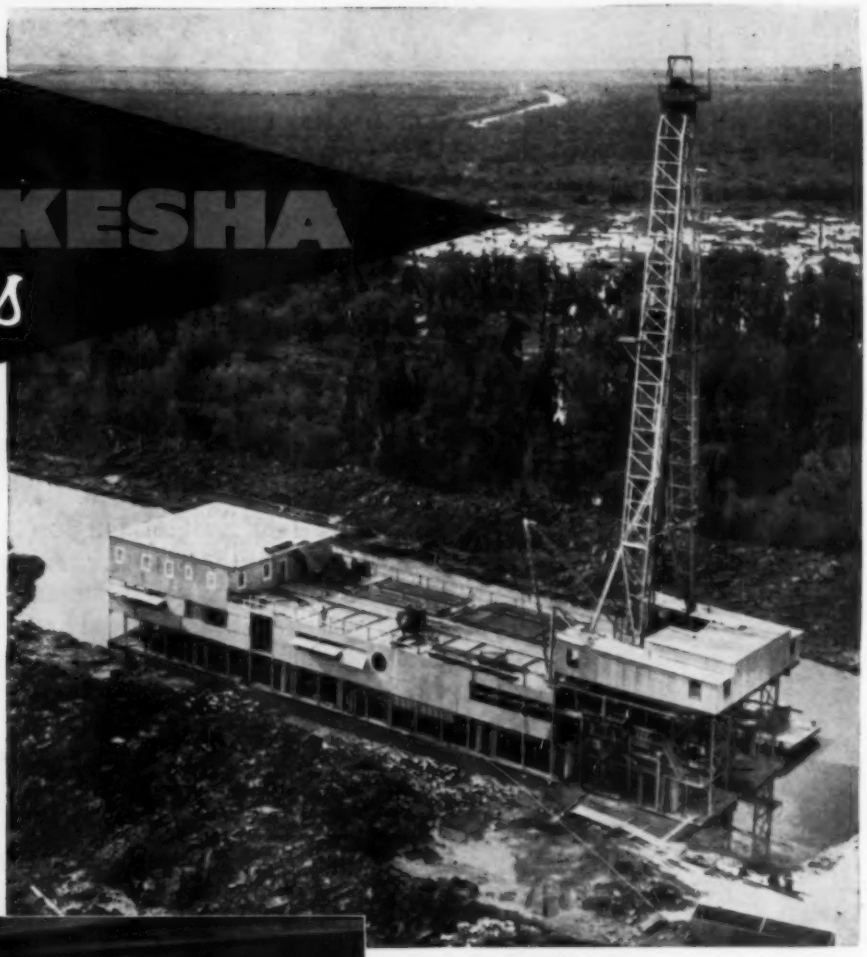
ONE OF THE BEST YEARS IN ROCKY MOUNTAIN HISTORY, in terms of new oil found, is predicted by Petroleum Information. Total wells drilled are expected to reach 4700. This is not a record. Drilling in North Dakota is showing moderate increase, and Utah rig activity is very high, percentagewise. Rocky Mountain states had 22 more oil or gas discoveries in the first six months of this year than in the first half of 1956.

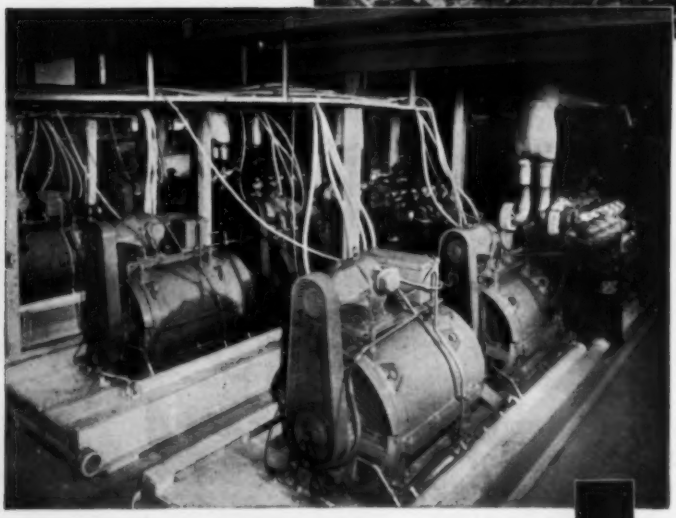
WASHINGTON STATE BOOM will be more leasing activity than drilling activity — at least for many months to come. State officials are processing leases on public lands "meticulously," even as private individuals are asking for — and getting — prices many times the original worth of the land itself. Center of interest is on the Olympia Peninsula near Hoaquim, near the site of Sunshine Mining Company's new well. The strike represents the state's first commercial oil well.

five WAUKESHA Diesels

on RIG 6 of the CIRCLE DRILLING COMPANY

SUPPLY ALL POWER





• Circle Drilling Company's 143-ft. Rig No. 6—mounted on their 52 x 220 ft. barge *Kirk C. Lewis* which operates in water to 18 ft. in depth—is one of the world's largest Diesel-electric outfits. Shown here at Week's Island, La., it is drilling a 17,000 ft. well for a major oil company.

Three Waukesha V-12 Diesels—each driving two 540 KW, DC generators—supply power for the Ideco E-2500 drawworks, and rotary; and two Emsco D-1000 slush pumps. These three Waukesha V-12 Diesels are Model VLRDBSU—12-cyl., 8½ x 8½-in., 5788 cu. in., counterbalanced crankshaft—have exhaust driven dual turbochargers for extra power.

Two additional Waukesha Diesels—driving two 200 KW, AC generators—supply power for rig lighting and other auxiliary needs. The mud-mixing pump is an Emsco D-300. These two Waukesha Diesels are Model NKDBSU, 6-cyl., 7 x 8¼-in., 1905 cu. in., turbo-supercharged engines with counterbalanced crankshafts.

Send for Bulletins 1663 and 1634

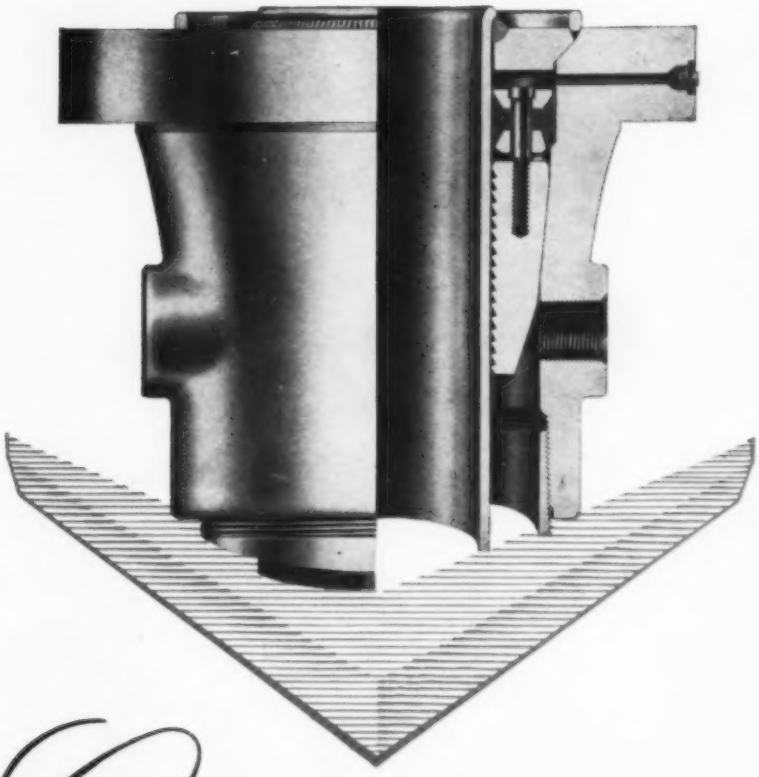
WAUKESHA Engines and Power Units: 10 hp to 1235 hp—Turbocharged and Normal Diesels • Natural Gas • LP Gas

Get Bulletin 1079

WAUKESHA MOTOR COMPANY
WAUKESHA, WISCONSIN
New York • Tulsa • Los Angeles

347-R

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD



THE *Cadillac* OF CASING HEADS

RECTORHEAD Casing Heads have achieved their place in the industry through the design of the Rector Welding Ring and application of API ring gasket which makes the metal-to-metal seal between strings possible.

This "ring-of-steel" seal not only simplifies high pressure casing head installation, but provides a seal that will not burn out, deteriorate, flow under high pressure or temperature, requires no maintenance or replacement, and eliminates pressure equalization between strings.

The 60,000 Rectorhead Casing Heads, with all-metal, welded seal, installed during the past 25 years, have been a vital factor in "Making the Oil Industry Safer."

Sold through authorized supply stores.

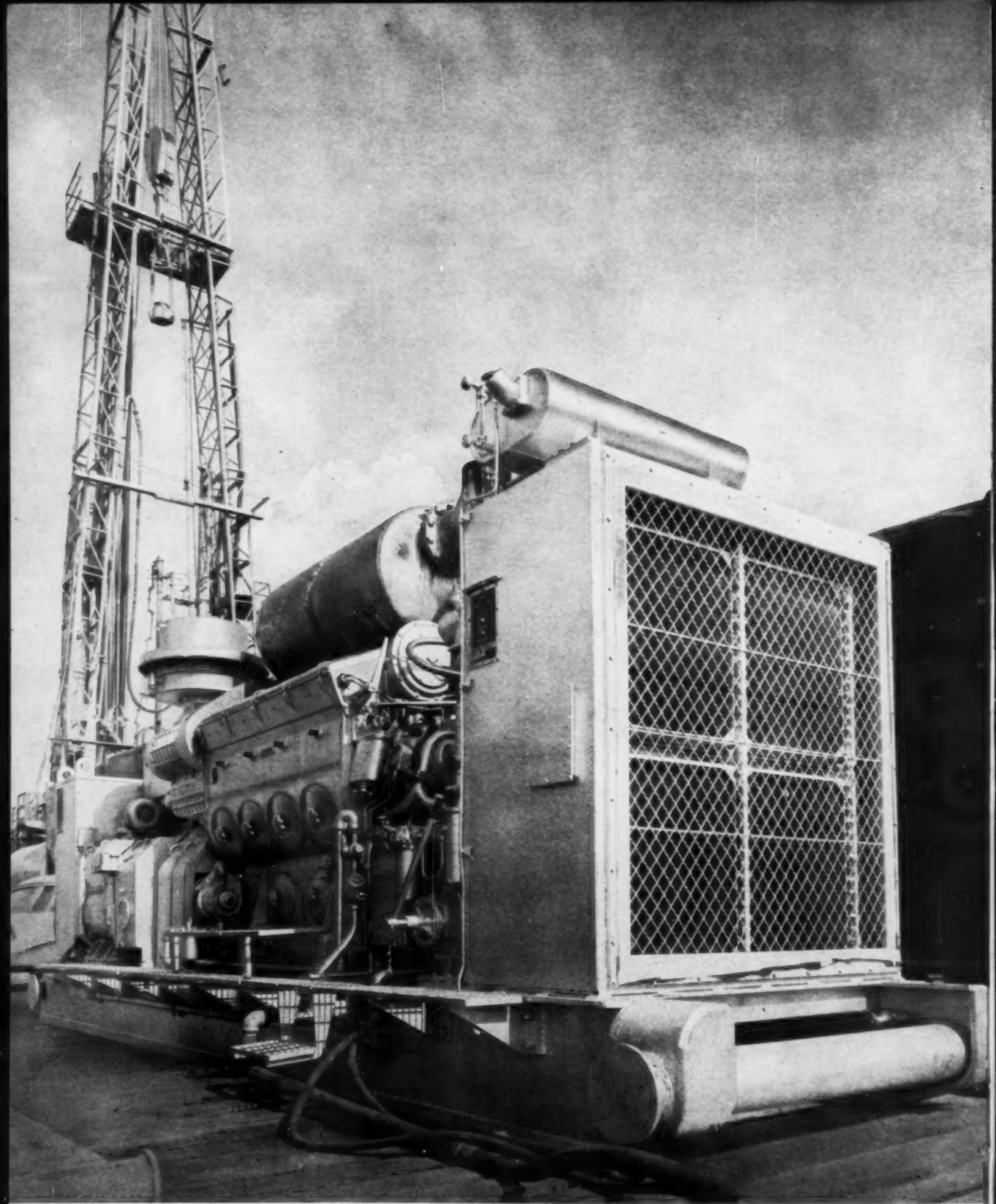
RECTOR WELL EQUIPMENT COMPANY INC

★ MAKING THE OIL INDUSTRY SAFER

1100 NORTH COMMERCE ST. FORT WORTH, TEXAS

Houston Plant: 2215 Commerce St.

REPRESENTATIVES IN ALL ACTIVE FIELDS



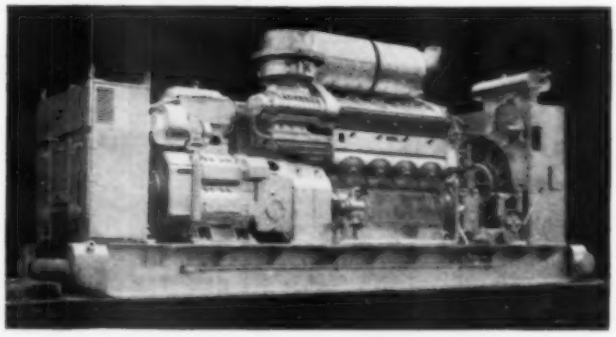
In operation on Sun Oil Company's Rig 15 at Rayne, La. is Electro-Motive's new drilling power unit, the SR-10. Main features include increased engine hp, increased generator and drive motor capacity, lighter weight, integral AC generator, simplified maintenance and load regulator control.

Announcing
a significant advancement in
deep well drilling power

New Electro-Motive SR-10 Power Unit

In 1955, Electro-Motive introduced the first fully integrated Diesel-electric power system for oilwell drilling. Success of these units is demonstrated by the fact that Electro-Motive Power is widely used by drilling companies throughout the Gulf Coast area.

Now, Electro-Motive offers another first and significant contribution to the oil industry's increasing need to drill deeper, faster and more economically — the first standardized, completely self-sufficient Diesel-electric power system. These are its features:



The SR-10 is a refinement of Electro-Motive's original plan to build a *complete* and integrated Diesel-electric system designed and built to work as a unit with one manufacturing responsibility.

For detailed specifications on the new SR-10 unit, contact your Electro-Motive representative in any of the cities listed below.

INDEPENDENT AC SUPPLY

A new integral AC generator (100-KW) makes the SR-10 completely independent of outside supply for its own AC needs—blowers, exciters, control equipment.

INCREASED POWER

Engine horsepower has been increased to 1000. New D49-G generators produce up to 640-KW each (2 per engine). New D49-M drive motors deliver up to 800 horsepower.

GREATER POWER UTILIZATION

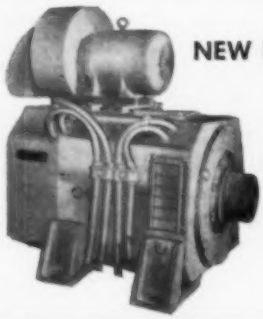
New load regulator provides load balance between units. Thus, if power requirements exceed that available on one unit, the load regulator automatically loads a second unit to satisfy drilling demands.

REDUCED MAINTENANCE

New improved motor control cabinet is simpler and more efficient. Its new design combines with many other improvements, both electrical and mechanical, to appreciably reduce overall maintenance time and expense.

LIGHTER WEIGHT

A new speed-increasing transmission between the engine and generators and other changes have cut the weight of the air cooled unit by more than 2000 pounds.



NEW D49-M DRIVE MOTOR

Improvements in design and materials of both the new motor and generator have appreciably increased horsepower and provided for better moisture protection. Motors and generators are identical except for field windings, a factor that facilitates service and reduces costs.

ELECTRO-MOTIVE DIVISION
GENERAL MOTORS · La Grange, Ill.

In Canada: General Motors Diesel Limited, London, Ontario
Petroleum industry sales offices: Dallas and Houston, Texas; Morgan City, Louisiana; Los Angeles, California.

BJ Power Tubing Spider

faster, surer, safer than hand slips!

INCREASES PERSONNEL SAFETY. Completely eliminates dangerous hand-setting. Slips are pressure-raised and pressure-set by the driller or tong man by a remote control pedal.

SPEEDS OPERATION. No physical effort or wasted motion. Eliminates need for back-up tong. Slips lock in *up* position while the stand is being run. Setting action automatically centers tubing.

EASY ON TUBING. Slips have an instant, positive grip . . . with minimum marking of tubing and without crimping.

HANDLES THREE TUBING SIZES. The BJ power tubing spider can accommodate 2⅜, 2⅞ and 3½" o.d. tubing strings with just a simple change of the unitized slip assembly.

VERSATILE. Slips can operate efficiently on tubing strings with gas-lift valves. With a minor adjustment, they work equally well with parallel strings. The spider speeds such operations as well completion, clean-out, workover and slim-hole drilling.

TWO SIZES AVAILABLE. Medium weight (50-ton capacity) is for depths to 10,000 feet and 50-psi working pressure. Heavyweight (75-ton capacity) has extra-long nine-inch slips. Working pressure, 60 psi.

CHOICE OF POWER SOURCES. Pneumatic- or hydraulic-powered models available. Can operate off rig pressure system or by BJ auxiliary trailer-mounted air-compressor or hydraulic-power unit.

COMPATIBLE WITH OTHER POWER TOOLS. This tool is a natural power partner to the BJ Powairmatic or Hydratorc tong for fast, efficient make-up and break-out of tubing and lightweight pipe.

WATCH BJ FOR THE NEWEST

Byron Jackson Tools, Inc.

A SUBSIDIARY OF BORG-WARNER CORPORATION

P.O. Box 2017A, Terminal Annex, Los Angeles 54, California • Cable: "BJTOOL"
Export Address: 580 Fifth Avenue, Suite 510, New York 36, New York

NOW—your choice of THREE derricks for use with the Bucyrus-Erie 48-L

For deep hole drilling and servicing performance at its versatile, moneymaking best, you NOW have a choice of *three* derricks for use with the field-proved Bucyrus-Erie 48-L spudder. Each is specifically designed to handle your different kinds of work:

1. The *Standard 61′ Derrick* for normal top-to-bottom drilling to 6,000 feet and well servicing to 7,000 feet;
2. The *Special Heavy Duty 70′4″ Tripod Derrick* for heavy tool and casing work (handles up to 300,000-lb. casing loads with 10-part hoist);
3. The *Special 85′ Servicing Derrick* for deep well workovers (handles up to 60,000 pounds of tubing, easily racks 30-ft. doubles).

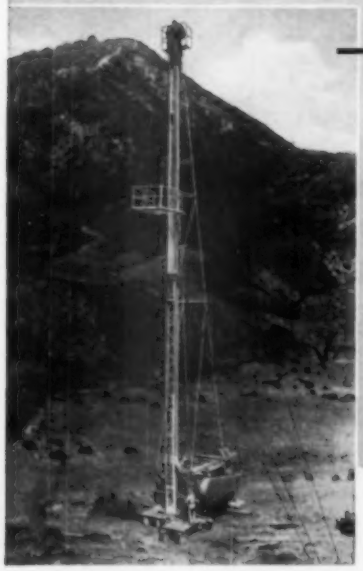
Look over the illustrations and specifications. Select the derrick best suited to your needs. Then, use the coupon to get the full story.

BUCYRUS ERIE

SOUTH MILWAUKEE, WISCONSIN

Standard— field-proved and unexcelled for strength and durability; telescopes to 38′3″; power-raised and power-lowered for quick, easy setups; swings up to 6,700-lb. tool strings; handles tackle pulls up to 160,000 pounds with auxiliary A-frame.

Tripod— the choice where a heavier derrick of greater height is required; power-raised and power-lowered; five-unit assembly is easily erected, quickly torn down for moves . . . each unit transported separately for convenience.



Servicing— a compact traveling unit with the necessary extra height, big capacity and strong structural design; telescopes and is power-lowered to lay down over the spudder for fast road travel; power-raised for easy field erection. Fingerboard arrangement holds up to 7,920 feet of tubing in 60-ft. stands.

FIRST with the FINEST in Spudders

BUCYRUS-ERIE COMPANY

South Milwaukee, Wisconsin

Please send me further information on the following derricks for use with the 48-L:

☐ Standard ☐ Tripod ☐ Servicing

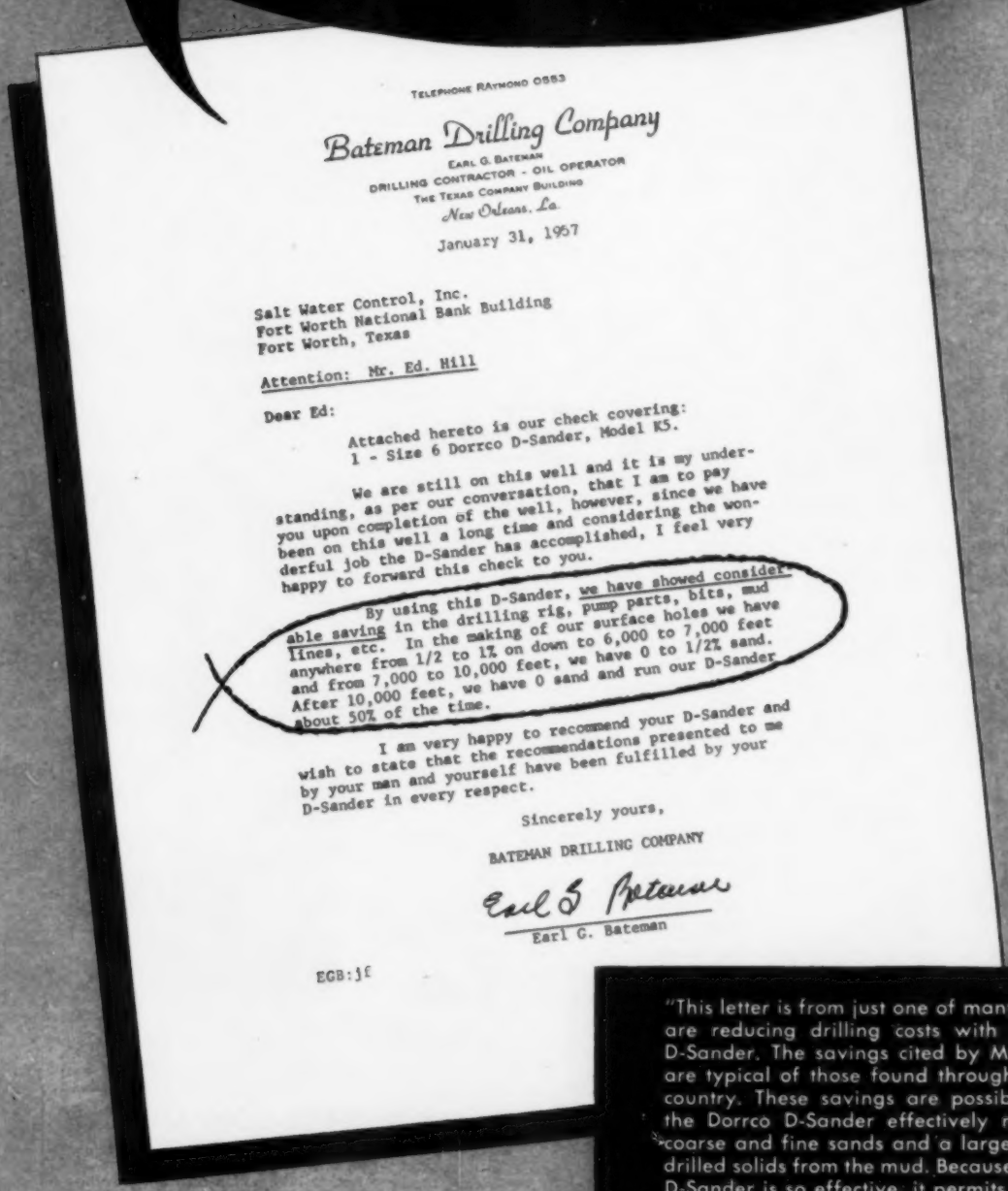
NAME.....

ADDRESS.....

CITY..... ZONE..... STATE.....

43557

"...we have showed considerable saving..."



TELEPHONE RAYMOND 0883

Bateman Drilling Company

EARL G. BATEMAN
DRILLING CONTRACTOR - OIL OPERATOR
THE TEXAS COMPANY BUILDING
New Orleans, La.

January 31, 1957

Salt Water Control, Inc.
Fort Worth National Bank Building
Fort Worth, Texas

Attention: Mr. Ed. Hill

Dear Ed:

Attached hereto is our check covering:
1 - Size 6 Dorrco D-Sander, Model K5.

We are still on this well and it is my understanding, as per our conversation, that I am to pay you upon completion of the well, however, since we have been on this well a long time and considering the wonderful job the D-Sander has accomplished, I feel very happy to forward this check to you.

By using this D-Sander, we have showed considerable saving in the drilling rig, pump parts, bits, mud lines, etc. In the making of our surface holes we have anywhere from 1/2 to 1% on down to 6,000 to 7,000 feet and from 7,000 to 10,000 feet, we have 0 to 1/2% sand. After 10,000 feet, we have 0 sand and run our D-Sander about 50% of the time.

I am very happy to recommend your D-Sander and wish to state that the recommendations presented to me by your man and yourself have been fulfilled by your D-Sander in every respect.

Sincerely yours,

BATEMAN DRILLING COMPANY

Earl G. Bateman

Earl G. Bateman

EGB:jf

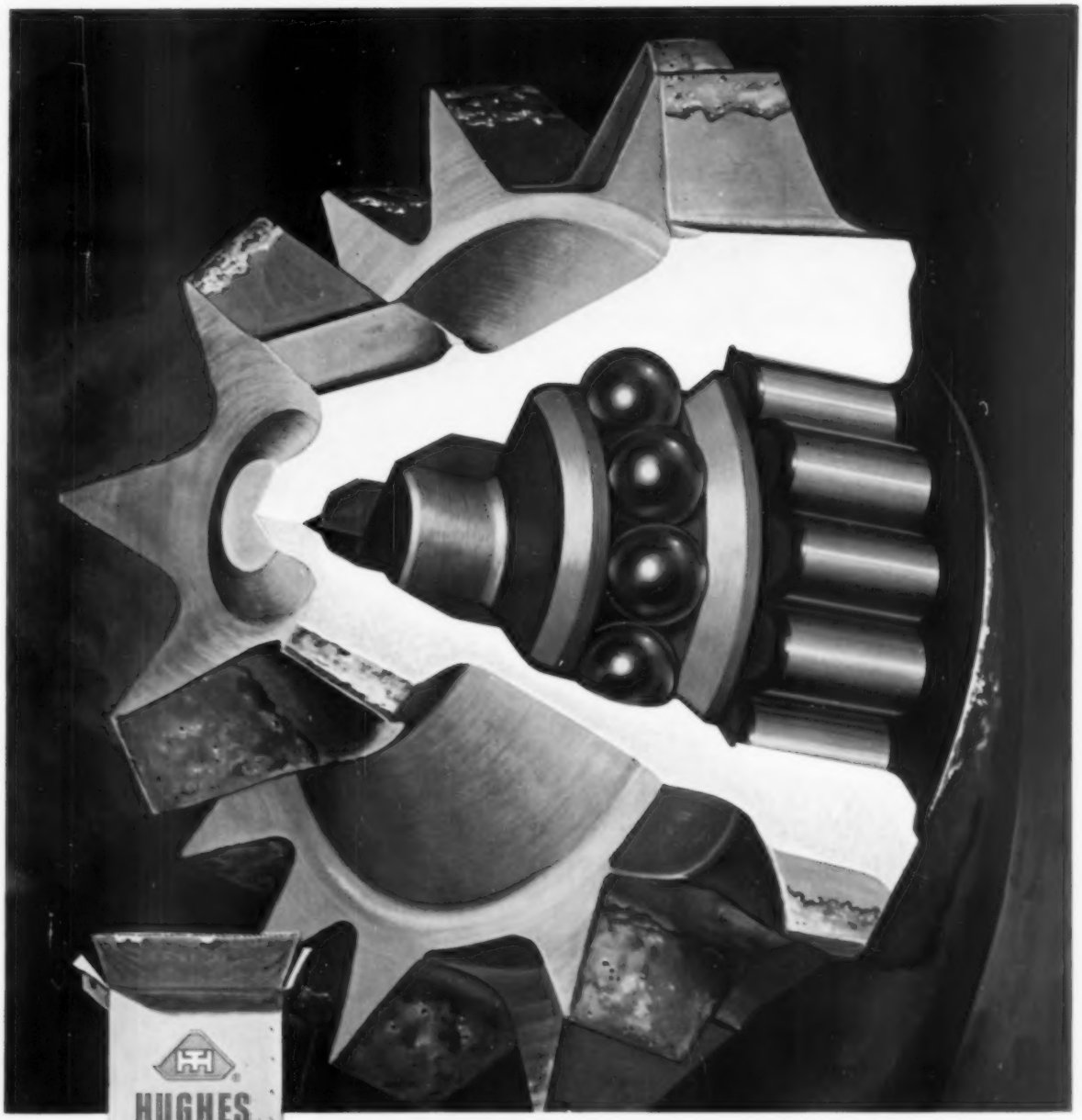
"This letter is from just one of many users that are reducing drilling costs with the Dorrco D-Sander. The savings cited by Mr. Bateman are typical of those found throughout the oil country. These savings are possible because the Dorrco D-Sander effectively removes all coarse and fine sands and a large portion of drilled solids from the mud. Because the Dorrco D-Sander is so effective, it permits substantial savings in areas where normal sand and solids contents were formerly considered low. Contact Salt Water Control for more information and arrange for a trial on your own operations."

SWACO

SALT WATER CONTROL Inc.

A Sid Richardson Development Company

1211 Ft. Worth National Bank Phone: ED 2-4434 Ft. Worth, Texas

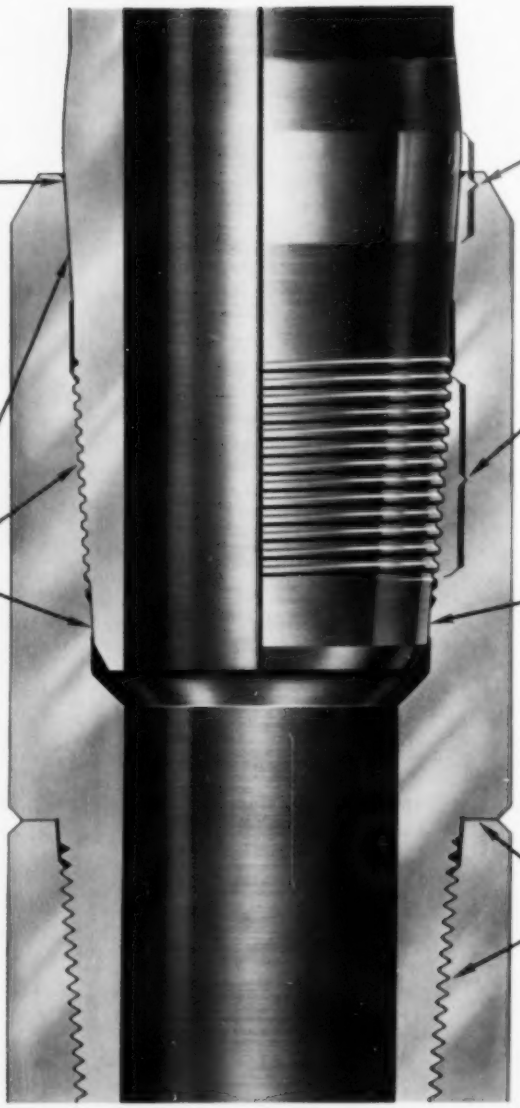


A STOUT HEART... for Longer Life

One of the big reasons you are today getting increased footage with Hughes rock bits is the improved quality of the bearings. The design and metallurgy of Hughes bearings have never been permitted to remain static.

Teams of product, research, metallurgical and field engineers are constantly evaluating designs and materials to determine the combinations that will deliver the best results. Aiding materially in this evaluation is the physical examination of the bearings of thousands of selected dull bits sent to the Research Laboratory each year from the various fields with their performance records.

The work of these engineers, backed by Hughes' nearly 50 years experience with rock bits, is being reflected in the continued improvement in bit performance.



Steep taper permits thick section at point of last contact between pipe and tool joint where bending loads in pipe are greatest.

This critical area of the pipe is **cold-rolled** at the mill for greater strength, using equipment and techniques developed by Hughes engineers.

Engaged thread strength in shear is greater than two times the strength of the drill pipe.

All mating surfaces — the outer seal, pipe threads, and inner seal — are on the same taper. This provides uniformity of fit on initial and replacement installations.

Nose seal is on taper to assure uniformity of fit and positive seal against leakage, on both original or replacement installations. This prevents corrosive fluids attacking threads.

The three points of engagement of the "Seal-Grip" joint provide a FRICTION GRIP stronger than the torsional strength of the pipe.

Copperplating of threads and shoulders of Hughes tool joints protects against scoring and galling.

Hughes offers improved SEAL GRIP assembly

The process and equipment developed by Hughes for cold rolling the large land area of the drill pipe at the pipe mill produce a superior "Seal Grip" assembly unequalled in strength and dependability.

In laboratory fatigue tests—*where pipe is run to destruction*—we have not been able to induce a single failure in the cold-rolled area of the pipe. This added feature plus superior design makes HUGHES "Seal Grip" today's best buy in replaceable tool joints.

HUGHES TOOL COMPANY

Developers of "Flash-Weld," "Seal Grip" and Counterbore Weld Tool Joints

There's RESERVE CAPACITY in this LIGHTWEIGHT PUMP

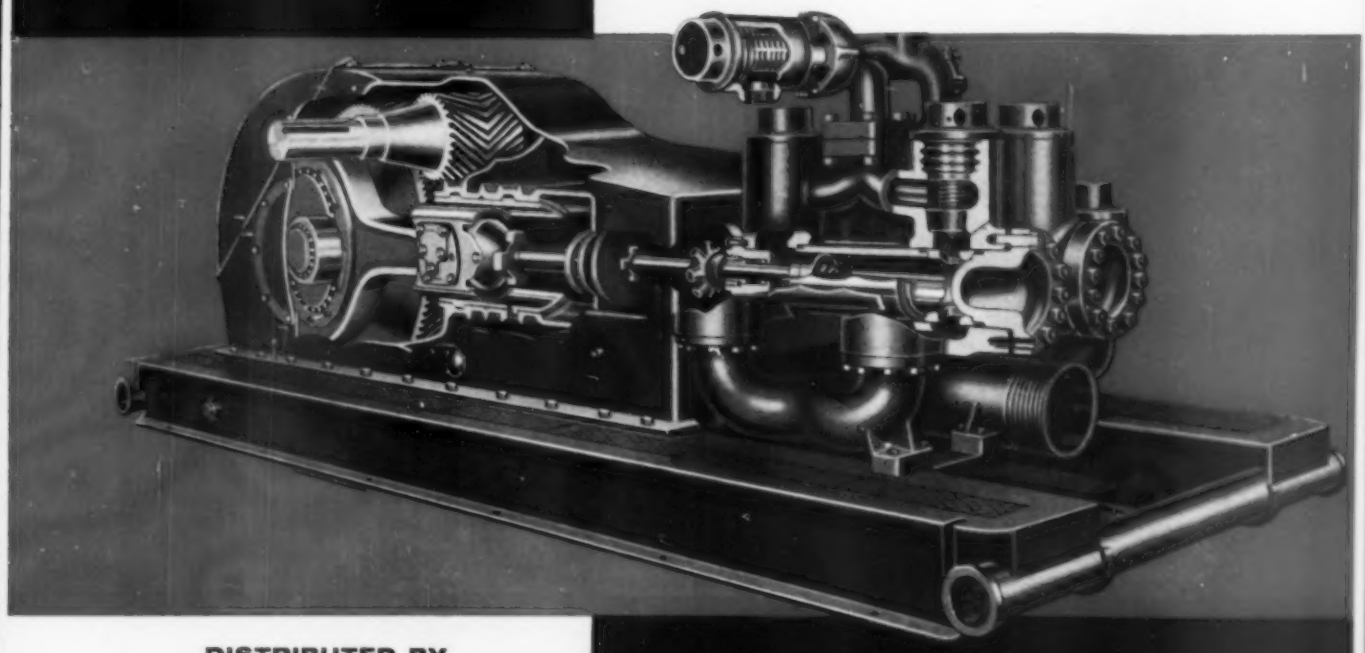
Examine this cross section of a Continental-Emsco Series D Slush Pump. Note how *extra power* has been built into the large main gear . . a wide-faced, forged-steel herringbone gear . . heat treated for years of heavy-duty pumping. The pinion and pinion shaft are integral . . made of high-alloy, forged steel . . fully heat treated.

Eccentrics are equipped with large diameter roller bearings, which results in an extremely narrow and compact power end. The eccentric straps are made of one-piece alloy steel.

You can see how the sides of the power-end housing are not thick, as are solid castings. Steel plates and shapes have been utilized instead of bulky castings to provide a light, rigid power-end. This is *Fabriform construction* . . the big *weight-saving* feature of Continental-Emsco Pumps for lower-cost transportation and easier rigging-up. You get *more horsepower per pound* than in any other slush pump.

Maintenance features are outstanding in the design of the D Series Slush Pumps. Patented "exposed" liner design *minimizes fluid-end washouts* caused by liner-packing failures, and no greasing is necessary, since lubrication is completely automatic.

One of these six Continental-Emsco Slush Pumps will meet your drilling requirements: D-175, D-300, DA-500, D-700, DA-850, D-1000. Ask your supply representative for all the data on these pumps.



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CONTINENTAL-EMSCO

Serving the Oil and Gas Industries ... Worldwide

SP708

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Hook onto real chain savings with REX® API CHAINS

Chain *isn't* the same. Not by a drilling site, it isn't. It takes special design features to put all the ruggedness into it that rig service demands.

There's your reason for Rex Balanced Design. This way, each chain component is balanced perfectly against the others—for greater strength, for added efficiency, for lasting performance. All parts are equally strong. Therefore, working load and stress are distributed over-all. No one part is singled out to do more than its share of the job. It's high-strength design without excess weight.

Rex builds greater wear resistance and long life into each part through careful attention to hardening, finishing and precision.

Another Rex API Chain advantage: unique 3-diameter pin speeds and simplifies assembly and disassembly—more chain working time, more money saved.

Keep drilling time up and chain costs down. Ask your supply store or Rex Field Sales Engineer about Rex API Chain. Or write for Catalog 55-3. CHAIN Belt Company, 4719 West Greenfield Avenue, Milwaukee 1, Wis.

CHAIN BELT COMPANY

Milwaukee 1, Wisconsin

Oil field district offices in: Dallas • Houston • Midland • Los Angeles • New York

you'll see load after load of

CF&I SEAMLESS CASING and TUBING

in the Denver-Julesburg Basin

There are good reasons for such acceptance. Every foot of CF&I Seamless Casing and Tubing is made under rigid quality controls to assure dependable service. And CF&I's mill at Pueblo, Colorado, is ideally located to give prompt, efficient service even on emergency rush orders. No wonder so many operators in the Denver-Julesburg Basin, and all over the West, depend upon CF&I Oil Country Goods!

Made to API STD 5A specifications, CF&I Seamless Casing and Tubing is available in popular sizes from 2⅜" through 9⅝" O.D.

3693

SEAMLESS TUBULAR PRODUCTS

THE COLORADO FUEL AND IRON CORPORATION
Denver, Colorado

CF&I

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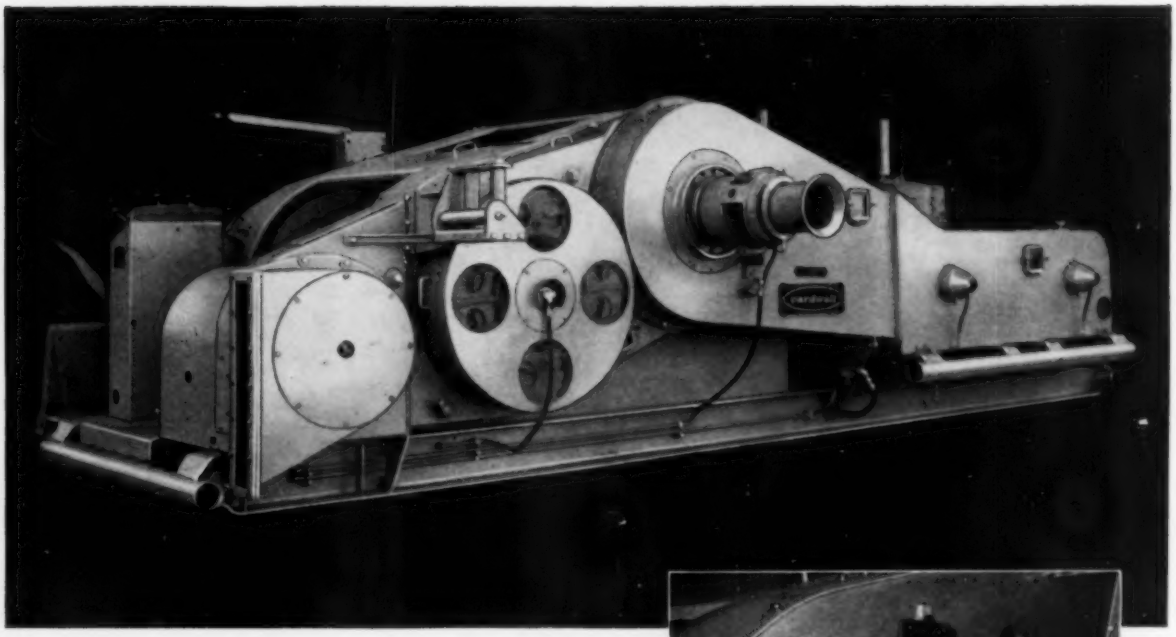
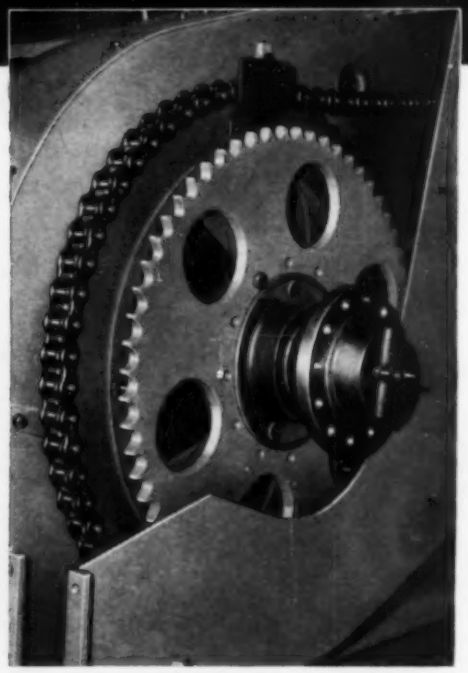




On the new Cardwell L-350

DIAMOND ROLLER CHAINS

Outstanding performance on leading makes of drilling rigs, pumpers, hoists and other oil field equipment has made Diamond Roller Chain the most widely used chain in the oil industry.

Experienced oilmen say why in these few words: "Diamond lasts longer." "Diamond requires less maintenance." "Diamond quality is *always* best." "Diamond cuts drilling costs."

On new equipment, or as replacement roller chains, make sure you get Diamond.

DIAMOND CHAIN COMPANY, Inc., Dept. 441,
402 Kentucky Avenue, Indianapolis 7, Ind.
Tulsa Office: 2238 Terwilleger Blvd.
Offices and Distributors in All Principal Cities.

Please refer to the classified section of your local telephone directory under the heading CHAINS *or* CHAINS-ROLLER

THE TRADE MARK ◇ IS ON EVERY LINK

DIAMOND ROLLER CHAINS

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

Over 70 *Locations in the United States and Canada*

McCullough® REPORTS TO THE OIL INDUSTRY

Service *Anywhere Anytime*

New Services • • • New Tools • • • New Methods • • • Outstanding Results

Radiation Logger Gives Accurate Detail in 98% Saturated Brine Fluid

This was a multiple well logging project in brine wells in a Michigan field. All operations were performed above 2000'. Wells were cased with 3" O.D. pipe inside of 6" O.D. casing. Fluid was 98% saturated brine solution.

The 14 wells in this particular project were logged with 1¾" O.D. McCullough Radiation Well Logging instruments, averaging 1½ hours working time per well.

Because of the heavily saturated brine solution, other types of logging instruments had not been able to provide required information. All McCullough logs were sharp, clear and detailed. Location of casing collars and bottom of pipe, information that had not been obtainable before, was clearly indicated.

McCullough

Radiation Well Logger

Have you received your copy of this new bulletin? Write to McCullough Tool Company, 5820 South Alameda Street, Los Angeles 58, California. We will send your copy by return mail.

The jobs described above are certified to be true field reports of services rendered.

Scintillation Counter Picks Thin Zones for 960 B/D

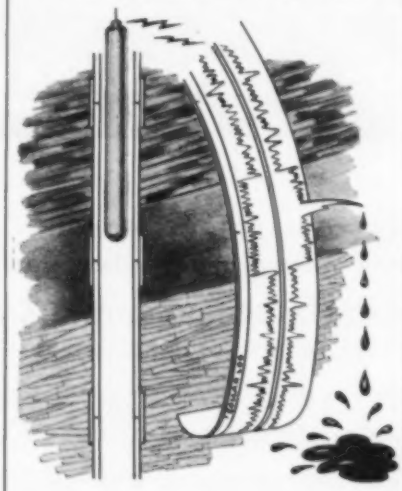
Accurate Down-Hole Information, Provided by McCullough Gamma Ray & Neutron Logs, Assured Pin-Point Perforating of Three 4' Zones For a Fine Producer.

Total depth of this Kansas oilwell was 3648'. 5½" O.D. 14 lb. casing had been set to bottom and cemented.

McCullough's Radiation Well Logger obtained Gamma Ray and Neutron Curves and a simultaneous collar log. Logging information was correlated with the operator's drilling log and three four-foot zones were picked as possibly productive.

The three zones were perforated, one at a time, by 3¾" O.D. McCullough Standard Casing Glass Jets in Steel Strip Carriers. A total of 52 shots were fired.

The lower zone proved to be water bearing and a bridge plug was set above the perforations, sealing off the zone. Upper zones were productive and made approximately seven barrels of oil per hour.



Exact measurement and definition of any potentially productive interval, thick or thin, assures "putting the shots where they count" for greater production—more oil!

Well was then acidized and on test made 40 barrels per hour, or 960 barrels of oil per day. This was the best well in the field.

McCullough's Radiation Well Logger is the most reliable logging instrument available. It has greater stability, provides more detail and assures more accurate quantitative interpretation. The efficiency of the McCullough Scintillation Counter makes it possible to log thin zones with clarity and accuracy.

The simultaneous recording of a collar log means placing the perforations exactly where they are wanted—fully covering the productive formation. And, as in the above case, this means "best possible production"—the best well in the field.

McCullough® TOOL COMPANY

Cable Address: MACTOOL

LOS ANGELES
HOUSTON
EDMONTON

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

ALLIS-CHALMERS ENGINES MATCH YOUR NEEDS

MATCH YOUR PERFORMANCE STANDARDS — with Allis-Chalmers high-torque, high-usable-horsepower engines that *stay on the job.*

MATCH YOUR POWER REQUIREMENTS — from a wide range of sizes and types, 9 to 516 hp. Specify or install them in *all* your equipment.

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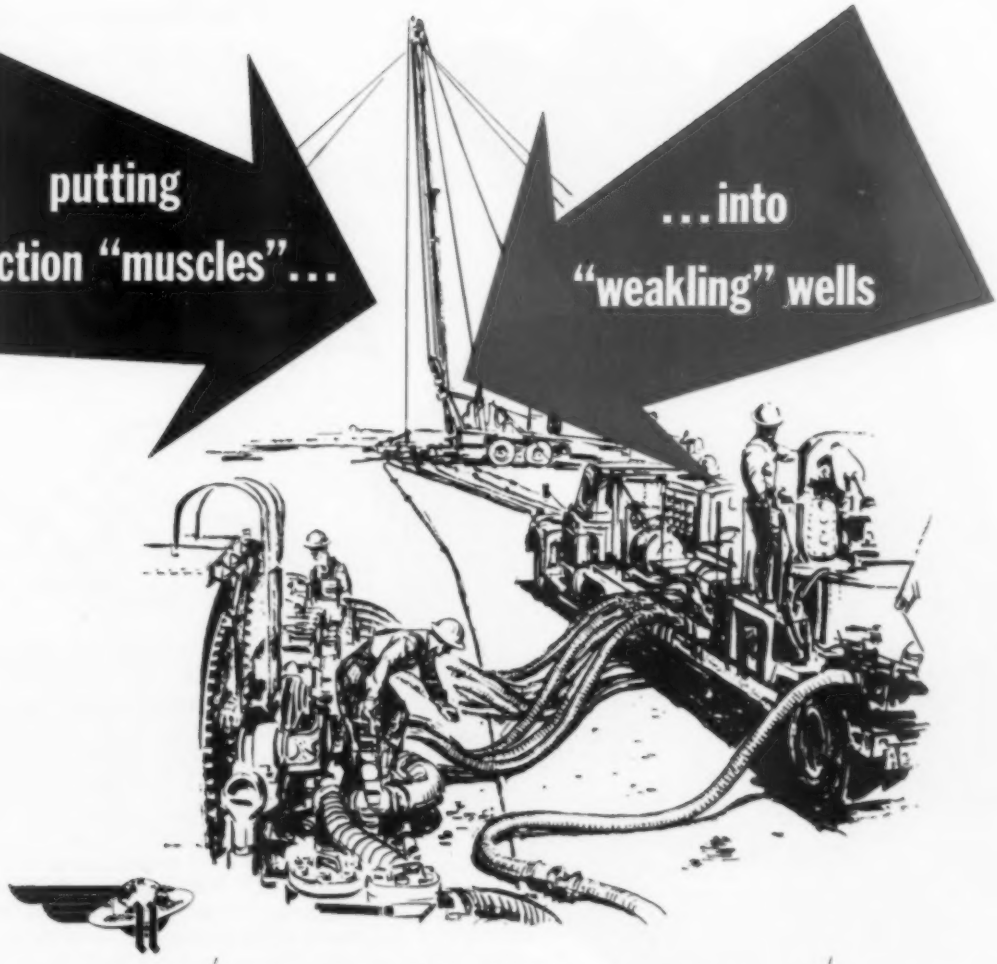

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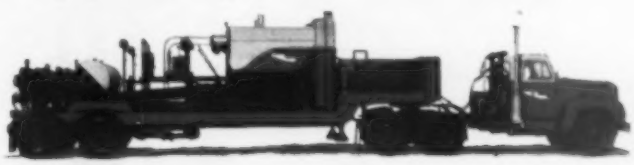

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Miscible Displacement With A Frontal Water Bank Is...

Latest Oil Recovery Idea

A water bank in front of an LPG slug followed by gas injection combines the favorable features of miscible displacement with waterflooding to improve: (1) Conformance; and (2) displacement efficiency... and achieve maximum ultimate oil recovery

Norman J. Clark, G. M. Andreen and A. J. Wessely,
Core Laboratories, Inc.
Dallas, Texas

A NEW twist has been added to the now-prominent miscible displacement process to offer maximum ultimate oil recovery from most types of reservoirs. As it is known today, miscible displacement briefly involves the injection of a LPG slug (or a rich gas) followed by conventional gas injection.

The new idea essentially consists of (1) injecting water into the reservoir, then (2) injecting a slug of LPG, followed by (3) injecting gas which drives both banks plus recovered oil through the pore channels of the reservoir. Purpose of this combination water flood and miscible displacement process is to gain both the advantages of waterflooding and those of miscible displacement. Since most sands are water-wet, the injected water bank tends to displace oil more efficiently from the "tight" or low permeability pore channels into the higher pore channels. In miscible displacement, oil is displaced more efficiently from the higher permeability pore channels than from the "tight" or low permeability pore channels. By combining both types of drives, using water ahead of the LPG to displace oil from the "tight" streaks, and the LPG to displace oil left in the higher permeability pore channels, maximum ultimate oil recovery can be attained.

Displacement Considerations

Recovery of oil from a reservoir rock occurs by the action of some displacing fluid. The degree of recovery is viewed in the light of three displacement considerations. These are pattern efficiency, conformance efficiency, and displacement efficiency. Maximum economic recovery of oil from a reservoir can be attained only to the degree that these factors can be determined and utilized in production operations.

Pattern efficiency denotes the areal portion or coverage of the reservoir through which the displacing medium can move from its source to the producing well or wells. Pattern efficiency is controlled generally by the geometric nature of the reservoir and the point of entry into the reservoir of the displacing fluid. The displacing fluids almost exclusively involved are natural gas or water from the natural sources by either gas cap drive or water drive, and from man made sources by either gas injection or water injection projects.

While the basic geometric nature of the reservoir cannot be altered, the pattern efficiency of the displacing fluids can be controlled to some degree by the location, rate, and timing of fluid production and injection, or the manner in which the normal drive is controlled. The various geometric patterns of water injection in the case of waterfloods, such as five-spot, nine-spot, line drive, etc., are recognized and well known; however, pattern considerations are applicable to all reservoir oil displacement operations, including reservoirs under primary producing conditions. These various operations must be studied and the best pattern utilized if maximum reservoir coverage by the displacement is obtained.

Conformance efficiency denotes that fractional portion of the total pore volume within the pattern area which the displacing fluid can affect or through which it can move. On the other hand, the remainder of the pore volume of the reservoir, considered as the nonconformance portion of the reservoir, is that fractional portion of the pore volume within the pattern area through which the displacing fluid cannot

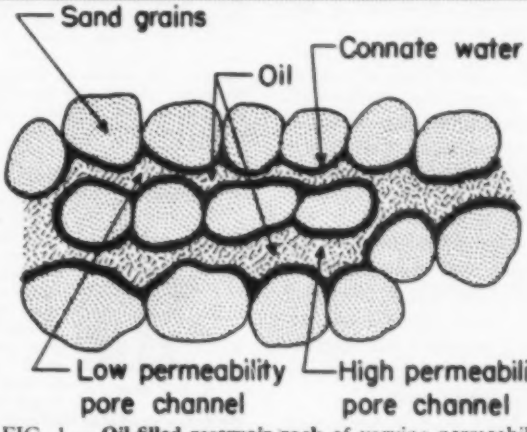

FIG. 1 — **Oil-filled reservoir rock** of varying permeability at initial saturation conditions.

move, or that portion which it does not affect. Conformance efficiency within a reservoir is controlled by several factors including the heterogeneity and distribution of the rock interstices, the capillary characteristics of the rock, the type of displacing fluid with respect to the rock wettability, viscosity of the two fluids, and the velocity at which the displacing fluid is moving through the rock.

Displacement efficiency denotes the percent recovery of the initial oil held in the conformance volume resulting from the action of the displacing fluid. Displacement efficiency within the pore channels through which the displacing fluid moves is controlled by several factors including some of the factors that control the conformance efficiency. These include viscosities of oil and displacing fluids, the velocity at which the displacing fluid moves through the pore channel containing oil, whether or not the displacing fluid wets the rock, and interfacial forces between oil and the displacing fluid.

The total percent recovery of oil to be expected from the entire reservoir then is the product of these three recovery efficiency factors for a given reservoir producing operation.

From the geological standpoint, there is one other extremely significant problem of oil recovery. That problem pertains to the stratification and lenticularity of the reservoir; however, the above recovery considerations pertain to the reservoir as a unit and with hydrocarbons initially in such reservoir being in capillary equilibrium and continuity. The stratification and lenticularity problem, therefore, is one of not being able to move the displacing fluid through all strata or lenses containing oil because of their not being in capillary continuity or equilibrium. A discussion of this particular problem as it affects oil recovery, however, is not within the scope of this paper.

For many years reservoirs have been studied to improve oil recovery utilizing relative permeability data, with such data being laboratory measurements on reservoir rock that represent the influence of capillary forces on the retention of oil in the rock pore spaces. Recovery expectancy is determined as the difference between initial oil in place and the oil retained after a displacing fluid is passed through the reservoir rock. These conventional basic studies were usually limited to equilibrium gas displacement or water displacement.

Within the last few years, laboratory studies and some field applications have been made of miscible displacement of oil. It has been conceived that miscible type displacement in certain cases will permit greater recovery than can normally be obtained by either equilibrium gas drive or water drive.[1, 2, 3, 4, 5, 6]

It is the purpose of this paper to describe generally an oil recovery process through which a maximum recovery of the initial in place oil can be obtained. This process utilizes the advantages to be gained in both conventional processes, equilibrium gas and water drive, and also the miscible displacement process.

It is well recognized that porosity and permeability of all reservoir sandstones vary from place to place in the reservoir and that limestones usually vary to a greater degree. This irregularity in porosity and permeability development presents one of the most important remaining obstacles in the way of total oil recovery. Original fluid saturation conditions in a non-uniform sand are illustrated in Fig. 1 by sand grains arranged to show a low permeability pore channel adjacent to a high permeability pore channel.

The Authors

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G. M. Andreen

Norman J. Clark is assistant manager of the engineering and consulting department of Core Laboratories, Inc., of Dallas, Texas. He received a BS degree in petroleum engineering in 1941 from the University of Oklahoma, and began his engineering-training with Humble Oil & Refining Company as a roustabout in Southwest Texas. After 3½ years in the Navy's Bureau of Ordnance during World War II, he returned to Humble. He specialized in reservoir engineering studies, developed and supervised reservoir engineering training schools, and set up and coordinated a company formation evaluation program. He joined Core Lab in June 1955. He is a member of AIME and a registered professional engineer in Texas.

G. M. Andreen is a senior petroleum engineer and heads waterflood studies in the consulting and engineering department of Core Lab in Dallas. He graduated from the University of Pittsburgh in 1942 with a BS degree in petroleum engineering. He spent the next four years as an engineering officer in the U. S. Navy and entered Magnolia Petroleum Company's engineering department in 1946. He worked for Magnolia as a field engineer, district engineer and in the proration department. He joined Core Lab in October 1955. He is a member of AIME and is a registered professional engineer in Texas.

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Water Displacement

It is a recognized fact that because reservoirs are nearly always water wet instead of oil wet, water as a driving fluid tends to displace oil first from the tight sections and dead end pore channels of the rock which contain oil by imbibition through capillary forces.[7] This occurs as an exchange action between volumes of water as it moves along the high permeability channels. This exchange of fluids between reservoir pore spaces of varying permeability, when the displacing fluid wets the reservoir rock, causes the conformance efficiency to vary for different displacing fluids. It is also greatly dependent upon whether or not the displacing fluid is rock wetting. This means in essence that the conformance efficiency will be much higher in the case of water drive where the water wets the rock than in the case of gas where the gas does not preferentially wet rock. The high efficiency of displacement of oil by the drive of a rock-wetting fluid, such as water, is therefore obtained from that portion of the reservoir which would be the non-conformance portion of the reservoir under conditions where the driving fluid, such as gas, does not wet the rock. In addition, water displaces fairly high percentages of oil from the high permeability channels of the rock leaving some residual oil in these channels and some smaller amounts in the tight low permeability channels. This is illustrated in Fig. 2.

Gas Displacement

The displacement of oil by gas occurs first in the largest of the pore channels. Capillary forces tend to retain oil in the smaller of the pore channels, and the overall capillary nature of the rock determines the amount of oil that can be displaced and recovered before a few large gas-filled channels provide sufficient flow capacity to permit only gas to move through the rock.

Miscible Displacement

The displacement of oil by a miscible drive is considered herein as one in which the displacing material is natural gas and miscibility occurs by

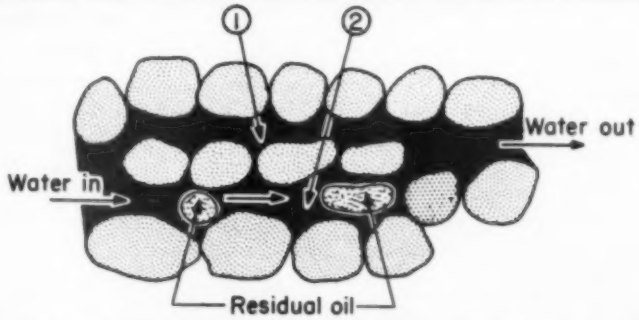

FIG. 2 — **Water drive displaces** a large percentage of all the oil from (1) low permeability channels by capillary forces. It leaves residual oil chiefly in (2) high permeability channels.

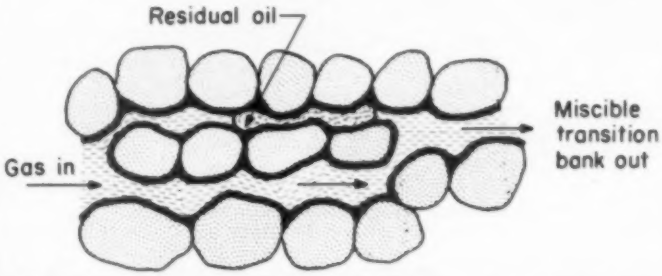

FIG. 3 — **Miscible drive displaces** all the oil from high permeability pore channels and some oil from low permeability pore channels before transition bank moves by.

means of a transition bank of hydrocarbon materials, such as ethane and heavier materials, between the gas and oil. Miscibility may be achieved either by "miscible slug" ahead of the injected dry gas or "condensing gas drive critical displacement" process.[3, 4, 5, 6] Miscible drive moves through the large pore channels and, only to some extent, in the smaller pore channels. As shown in Fig. 3, total recovery of oil can be expected from the channels through which the drive moves. Since this is considered the conformance portion of the rock, total recovery is attainable from the conformance portion. Miscible displacement of oil from sand-packed columns in the laboratory provides virtually total recovery because such columns have total conformance efficiency. When portions of reservoir rock are tested, total oil recovery may not be attainable because of the irregularity of the pore distribution. Fig. 4 illustrates that high recovery can be attained by miscible drive in those reservoirs where conformance volume is high. In those reservoirs with low conformance volumes, recovery by miscible drive would probably be intermediate as indicated in Fig. 5.

Comparison of Drives

In comparing the three basic drives for a given average sandstone reservoir, the conformance efficiency may be expected to be very high for water

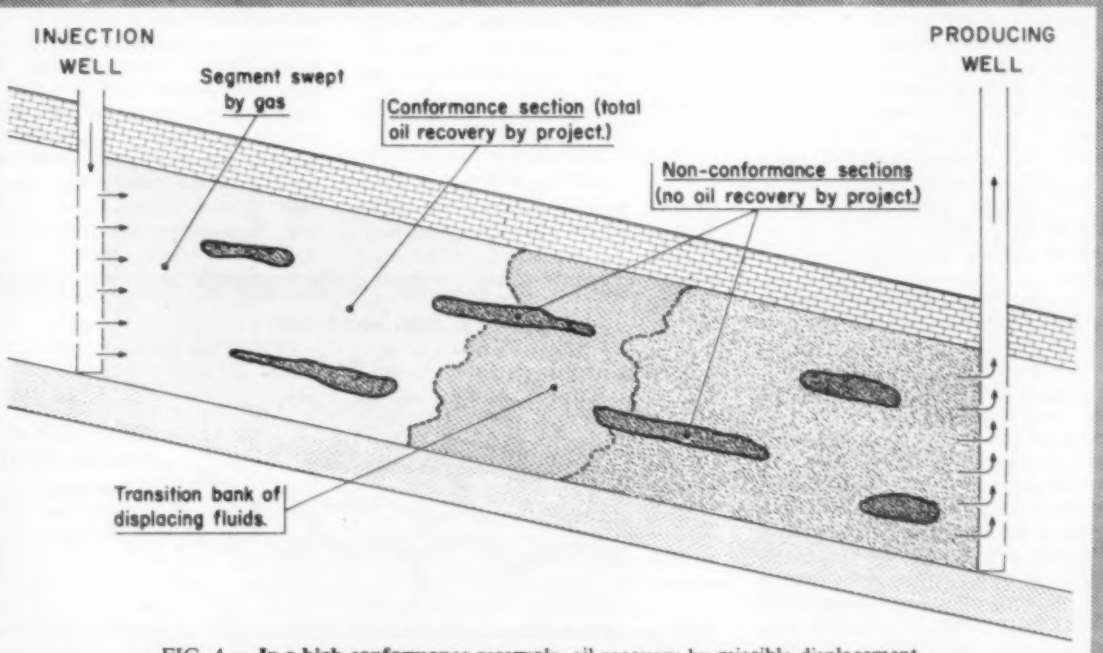
INJECTION WELL
Segment swept by gas
Conformance section (total oil recovery by project.)
Non-conformance sections (no oil recovery by project)
PRODUCING WELL
Transition bank of displacing fluids.

FIG. 4 — **In a high conformance reservoir,** oil recovery by miscible displacement is extremely high.

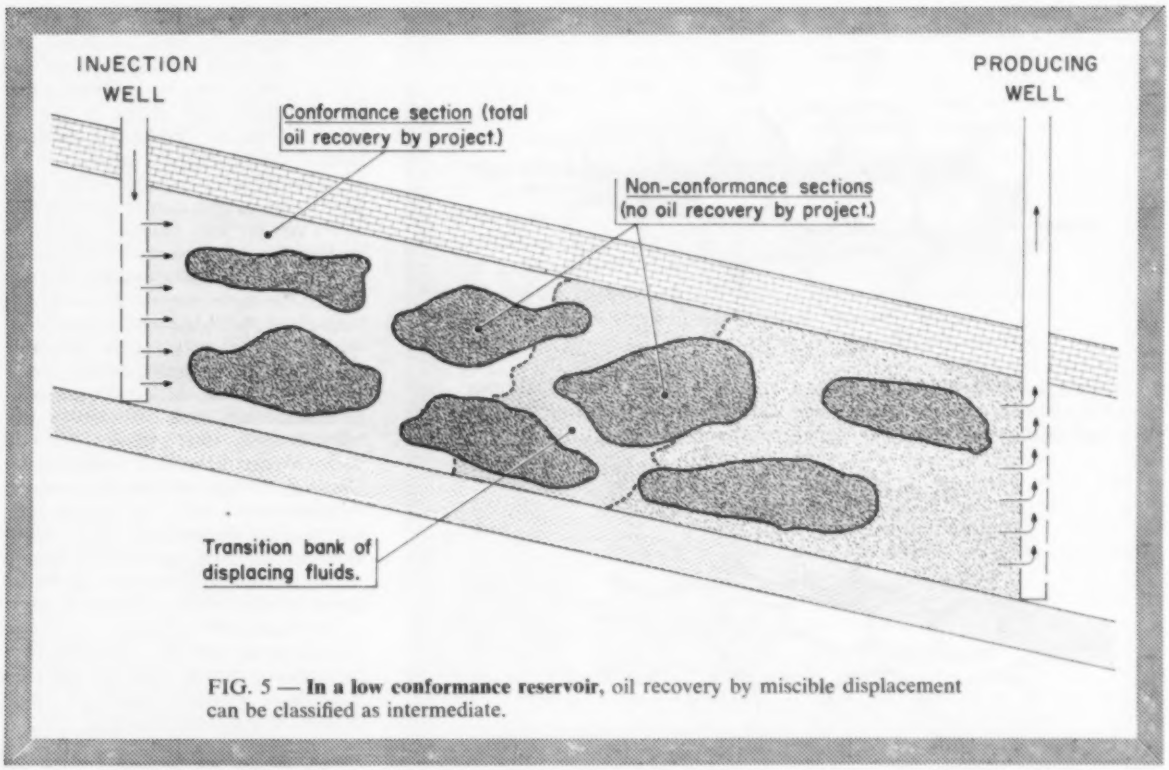
INJECTION WELL
PRODUCING WELL
Conformance section (total oil recovery by project.)
Non-conformance sections (no oil recovery by project.)
Transition bank of displacing fluids.

FIG. 5 — **In a low conformance reservoir,** oil recovery by miscible displacement can be classified as intermediate.

drive, intermediate for miscible drive, and low for equilibrium gas drive. Overall recovery efficiency can be expected to be intermediate for water drive, intermediate for miscible drive and low for equilibrium gas drive. In repetition, it is pointed out that water attains intermediate recovery from the overall reservoir by increasing conformance efficiency and recovering oil by capillary forces from remote pore spaces in the reservoir where other driving fluids fail to reach. Miscible drive attains intermediate recovery from the overall reservoir by obtaining total recovery in the portion of the reservoir through which the material moves.

For purposes of further discussion, equilibrium gas drive will be eliminated because miscible drive will provide better displacement and conformance efficiencies than will equilibrium gas drive, and concentrate our attention on the water drive and miscible drive cases. A comparison of these two cases shows that sand irregularity is the most important factor that controls oil recovery. Laboratory examinations show that water drive will attain only intermediate to high recovery if the sand is very uniform, while miscible drive will attain total recovery. If the sand is non-uniform, the recovery may be about the same or even in favor of water drive if the reservoir is very irregular. This is because of the large amount of non-conformance volume of rock under the miscible drive which will be swept by imbibition under water drive.

Combination Water Drive-Miscible Drive Process

If a reservoir is quite regular in porosity and permeability, and providing other lesser important factors are favorable, miscible drive can be expected to attain a maximum recovery of oil. If a reservoir has a certain degree of irregularity, however, a combination of water drive and miscible drive would be expected to attain a maximum recovery of oil. Since virtually all reservoirs are irregular in porosity and permeability distribution, a large portion of the oil reservoirs should fall in this category.

The combination water drive-miscible drive process illustrated in Fig. 6 involves first the injection of a bank of water which in turn is followed by a miscible displacement project. The water injected ahead of the miscible material moves into what would be the non-conformance portion of the reservoir under the conventional miscible drive process. This displaces the oil into the conformance portion of the

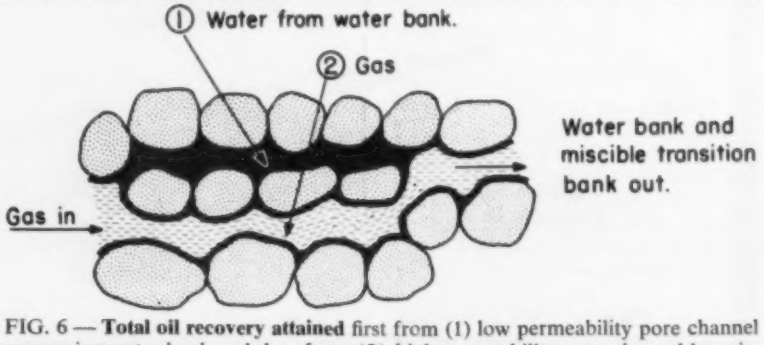

FIG. 6 — **Total oil recovery attained** first from (1) low permeability pore channel scavenging water bank and then from (2) high permeability pore channel by miscible transition bank.

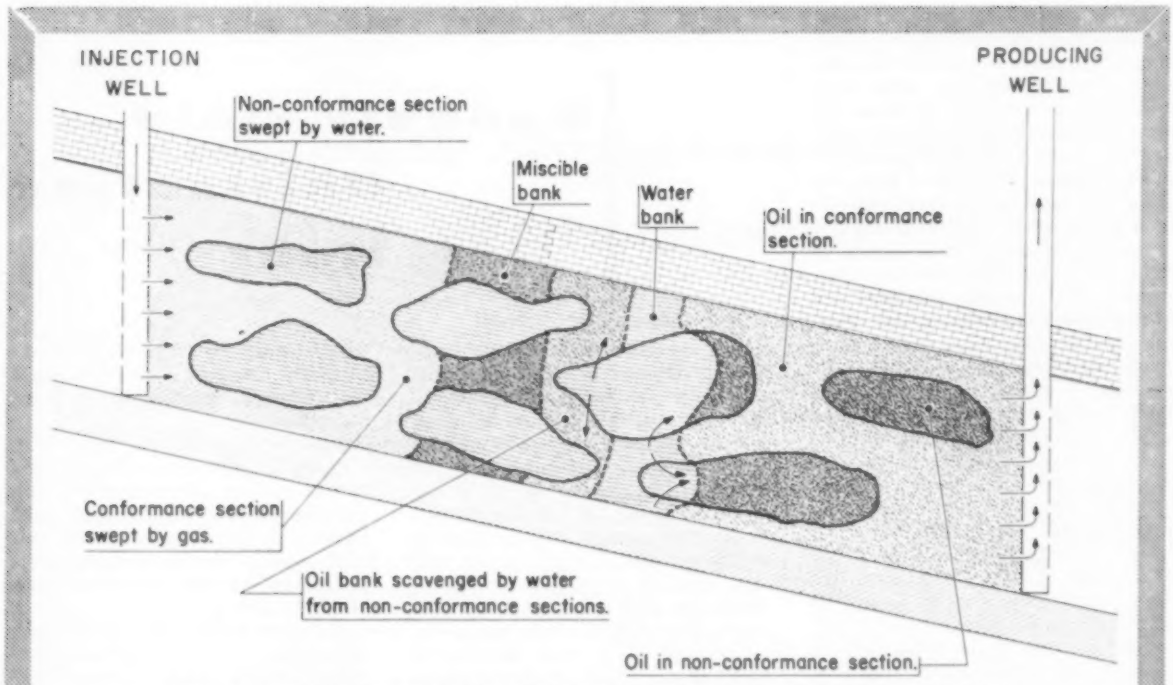

FIG. 7 — **Combination water drive-miscible drive project** in low conformance reservoir provides extremely high oil recovery by water in the non-conformance sections and by miscible displacement from the conformance sections.

reservoir. The injected water is thus exchanged for oil from the non-conformance low permeability portions of the reservoir and such water is therein retained immobile and not produced.

The oil that is moved out of the non-conformance portion of the reservoir and into the conformance high permeability portion of the reservoir thus becomes located so that it can all be driven to the producing wells by the miscible drive process to follow. The water can be considered as a scavenging agent to obtain oil recovery from the non-conformance portion of the reservoir where otherwise it could not be obtained by the miscible drive process. Such recovery is therefore obtained utilizing inherent capillary forces within the reservoir itself because the scavenging bank of water wets the rock in preference to the in-place oil.

Fig. 7 illustrates the water drive-miscible drive process that is designed to yield high recovery efficiency from low conformance volume reservoirs. In properly designing a project to obtain maximum recovery through use of a scavenging bank of water to increase conformance efficiency to a maximum and a miscible drive process to increase displacement efficiency to a maximum, it is desirable to be able to approximate reasonably well the magnitude of the conformance and non-conformance volumes of the reservoir within the pattern area of the project under a miscible drive project alone. This will provide information that will permit estimation of the quantity of water that should be injected as a scavenging bank ahead of the miscible injection materials.

The "Ideal" Project

The ideally designed project is one where just enough water is injected to be "smeared" throughout the reservoir, filling the non-conformance portion, with little or no water left to be produced from that which was injected into the reservoir. In addition, the ideally designed project will utilize only enough miscible materials, either LPG as a slug or in a rich gas mixture, to maintain a transition bank of critical mixture fluids between the oil and dry gas until the transition bank of fluids reaches the producing wells.

Under these conditions, the entire project is completed with dry gas occupying the pore space initially filled with oil in the conformance portion of the reservoir and with water, for the most part, occupying the pore space initially filled with oil in the non-conformance portion of the reservoir. The reservoir is then converted to a gas reservoir and can be produced by blowing down for gas sale or other use. If only a limited amount of gas is available to complete the miscible drive project, a water flood following the injection of a limited amount of dry gas behind the miscible drive front may be a sound consideration.

Because a miscible project would be designed to take advantage of any gravity segregation that could be utilized, it is possible that structural dip might not be favorable for follow up water injection because gravity forces would tend to aid water channeling.

In addition to minimum gas requirements, follow up water injection would be expected to increase pattern efficiency if proper well location cannot otherwise be economically obtainable.[5] The structural dip, even though it may be fairly great, would not be expected to interfere to any marked degree with the scavenging bank of water ahead of the miscible drive fluids because such water is not injected solely for the purpose of attaining high oil displacement efficiency in the overall rock volume. Instead it is injected to be absorbed and retained in the non-conformance volume of the rock by capillary forces and dip will not tend to detract from this purpose to an appreciable degree. Some structural dip may be beneficial, however, in order for the water to move down dip in front of the lighter gas materials and not be bypassed by the gas as it displaces oil to the producing wells.

As the scavenging bank of water moves through the reservoir, it tends to diminish in size and volume. The miscible drive following the water bank tends to create a bank of oil ahead and between the miscible transition zone and the water bank. The amount of this oil volume will depend upon the amount of non-conformance pore volume scavenged by the water bank.

Another advantage to be gained by the scavenging bank of water is in having the tight channels and dead end channels filled with water around which the miscible drive fluids will be effectively diverted, thus reducing the amount of mixing between miscible fluids and oil. This reduction in mixing tends to minimize the total amount of LPG or other miscible materials needed for the project. It is to be expected that some oil will be by-passed in the non-conformance rock volume even by water as the bank moves through the rock. Also, it is to be expected that some reservoirs will not be susceptible to water drive for various reasons, such as, the presence of clays that swell on contact with water. In such reservoirs the combination water-drive-miscible drive project may not be applicable.

In summary, the absolute maximum recovery of oil is achieved by a recovery process where the maximum pattern efficiency, conformance efficiency, and displacement efficiency is attained. Pattern efficiency is maximized by proper engineering design and is just so good as the geological interpretations upon which it is based. Conformance efficiency may be maximized through the use of a conventional water injection process. Displacement efficiency may be maximized through the use of a miscible drive process. Overall recovery efficiency, therefore, may be maximized by utilizing water drive followed by miscible drive with the best project having an optimum volume of water injected ahead of an optimum transition bank of miscible fluids to displace the oil.

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Preliminary approvals passed

Rangely Field Unitization Near

Life expectancy of Colorado's prolific Rangely oil field will be lengthened and its production possibly doubled through cooperative efforts of its operating companies and royalty interests and the support of various government bodies.

The Colorado Oil and Gas Conservation Commission has approved a unitization plan that now lacks only the signature of the United States Geological Survey — in favor of the plan — before final acceptance.

It was during the early development stages of the Weber reservoir that the operators agreed to the desirability of unitizing the field for gas injection purposes. Forming various committees, Rangely operators set about making the necessary detailed geological, engineering and economic studies for unitization of the complex Rangely reservoir.

The unit plan being approved is the sum total of 10 years of careful, cooperative and costly planning.

Rangely is a fully developed field in which, over an area of slightly more than 19,000 acres, 481 wells have been drilled. It is estimated that total production in the field to July 1 amounted to more than 225,000,000 bbl of oil.

Recovery Estimates

The engineering subcommittee of the Rangely Operators' Committee recently estimated that the amount of primary recovery would be 350,000,000 bbl. Similar estimates also revealed that the increased recovery due to gas injection and water flooding is potentially 385 to 437,000,000 bbl.

As an aid to unitization, operators have already installed facilities to inject produced Weber gas. Since September 1953, more than 97 billion cu ft of gas have been returned to the reservoir, the current injection rate being about 90 MMcf per day.

Owners

Principal working interest owners in the Rangely oilfield unit include the California Company, Phillips Petroleum Company, Husky Oil Company, Equity Oil Company, Utah Southern Oil Company, Pan American Petroleum Corporation, The Texas Company, Union Pacific Railroad Company, The Cameron Family, Tidewater Oil Company, and Sharples Oil Corporation.

As major owner of interests in Rangely, The California Company will be unit operator. The company, which maintains Colorado offices in Rangely, Denver, Grand Junction, and near Ault, already has plans underway to put the unit into operation immediately after its approval.

It appears that October 1 is a reasonable date on which to expect unitization of Rangely to become effective, reports a spokesman of the California Company.

Two-Phase Program

A two-phase program is being undertaken: First, gas injection (some of which is already being done), and secondly, waterflooding. To this end, engineers from the various operators have agreed on a pilot waterflood program. The pilot unit will then be enlarged to a full-scale program as soon as necessary technical data are available from the pilot tests. Gas injection will be necessary to conserve reservoir energy, as well as to provide for future fuel requirements in the field and plant. Ultimately the gas may be sold. Unitization is expected to permit a more efficient gas injection program than now in progress, operators say.

Flaring

Gas flaring, long a problem in Rangely, will not end overnight. But allowing a reasonable period of time for the construction and installation of additional gas handling facilities, it will be eliminated, except for operational flaring of small amounts.

History

Rangely is Colorado's largest single field. It is located in Townships 1 and 2 North, Ranges 102 and 103 West, in Rio Blanco County.

Shallow production in the Mancos was developed in 1902. The Weber sand, the principal reservoir in the field, was discovered in 1933. Development of the Weber occurred principally in 1945-46-47.

About 42 percent of the land in the field is Federally-owned.

Oil Recovery By...

Miscible Displacement After Waterflooding

About 10 percent of the oil remaining after waterflooding can be recovered, according to laboratory studies

A. W. Talash and Paul B. Crawford
Texas Petroleum Research Committee, A & M Division, College Station, Texas

SUBSTANTIALLY 10 percent of the oil remaining after waterflooding could be recovered by subsequent flooding with a miscible fluid. This was the principle result of laboratory studies to determine the quantity of oil that may be recovered by the application of a miscible flood after waterflooding.

By separation or fractionation and recirculation of the produced effluent, it may be possible to reduce the miscible fluid requirements by a factor of two or three.

Previous studies have indicated that the oil recovery from porous media may be substantially increased by the injection of miscible fluids. Everett, Gooch and Calhoun[1] have suggested that a high recovery could be obtained by displacing reservoir crude with miscible liquids. Results of the study made by Kennedy[3] indicate that the production of oil from depleted oil reservoirs may be substantially increased by the injection of liquefied petroleum gas. Kennedy's laboratory tests were made using a sand-filled oxygen bottle to simulate a reservoir. The sand was saturated with oil and then flooded with propane. Some of the recoveries obtained by this method were as high as 98 percent indicating that most all of the oil may be obtained by LPG injection.

Offeringa and Van der Poel[4] have presented information on the oil to be recovered by circulation of kerosine as a solvent through porous media. They conducted scale model experiments. The study included viscosity ratios of the crude oil to the kerosine from near 1.5 to 5000. It was found that the oil recovery at breakthrough when flooding with kerosine as a solvent, was equal to those obtained in waterflooding at the same viscosity ratio. However, after breakthrough occurred, it was found that by flooding with the kerosine (a miscible liquid) the flood becomes much more efficient than the water flood, and as a result, considerably more oil could be recovered by using the solvent flood than by using the water flood. It was their conclusion that the use of the kerosine flood followed by a water flood was not economically attractive at the present time because of the large quantities of solvent required. As a result, they devised a circulation process, or re-cycling process in which a portion of the effluent was returned to the injection well. By waterflooding the kerosine displaced core they were able to obtain recoveries of up to 95 percent. However, at mobility ratios near 5000, the ultimate oil recovery was near 68 percent. The kerosine remaining in the sand pack at the end of waterflooding varied from 15 to 17 percent over this mobility range.

Offeringa and Van der Poel concluded that the technique of using a kerosine or solvent flood was much more economical when applying recirculation. For example, in one case without recirculation, 6.50 pore volumes of kerosine had to be used to reach an oil recovery of 77 percent pore volume. With recirculation, a recovery of 81 percent was achieved with only 0.48 pore volumes of kerosine. Approximately 10 percent of a pore volume of kerosine remained in the pore space after a subsequent water flood.

Henderson, Gove, Ledbetter and Griffith[2] have performed experiments in which they studied the effect of oil viscosity, displacement rate, initial free gas saturation, and the effect of LPG injection preceding a water flood on oil recovery. In these tests, liquid isobutane was used to displace oil of varying viscosity from an Alundum core. Their conclusion was that the injection of iso-butane into the gas-oil water saturated systems prior to a water flood resulted in a marked increase in the effectiveness of the water flood. These investigators also found that an isobutane flood following a water flood suggested that the prior injection of water into a gas bearing sand might

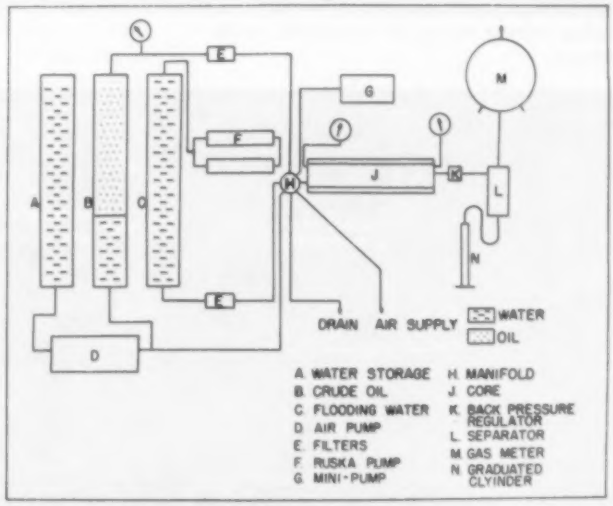

FIG. 1 — **Flow diagram** of experimental apparatus used in miscible displacement studies after waterflooding.

increase considerably the efficiency of a LPG flood; however, only one run was made to show this effect.

In present waterflooding techniques, the oil remaining in place after the water flood may equal the oil recovered by the water flood. Since only a limited amount of actual laboratory data have been presented in the past, the purpose of this study was to determine experimentally the oil recovered by miscible fluid injection following a water flood.

Displacement Studies

Fig. 1 is a flow diagram of the experimental apparatus. A Cetus oil-natural gas mixture with a bubble point pressure near 1033 psia at 110 F was used as the synthetic reservoir fluid. A 40,000 ppm brine solution was used when waterflooding. The porous medium consisted of an unconsolidated sand pack, 23 in. long and 1¾ in. in diameter. The permeability to distilled water was 3720 md; the porosity was 32.9 percent, and the total pore volume was 282.2 cc. A constant temperature of 110 F was maintained on the core and reservoir fluid storage tank.

A needle valve and back-pressure regulator controlled the flooding pressure at the outlet of the core. A lucite separator placed at the outlet end of the core served to separate the oil, water, and gas. The oil and water were measured with graduated cylinders, and the gas was measured with a wet-test meter.

A proportioning pump was used to initiate the water flood while a small capacity pump was used to pump crude oil solvent through the core. A high vacuum pump was used to evacuate the core.

Lab procedure. After initially cleaning and evacuating the core, four pore volumes of the brine solution were pumped through the core at a pressure of 1500 psia. The brine solution was displaced from the core by the synthetic reservoir fluid until no more water was produced, leaving a connate water saturation near 45 percent. Primary depletion of the core (by solution gas drive) was achieved by regulating the needle valve at the outlet end of the core and allowing the core to produce down to some predetermined pressure.

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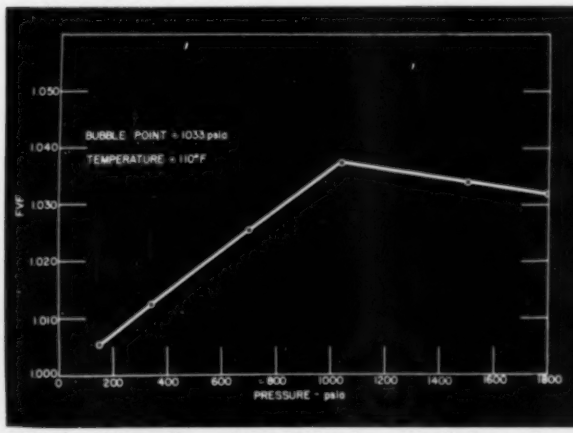

FIG. 2 — **Formation volume factor** for a synthetic crude oil-natural gas mixture.

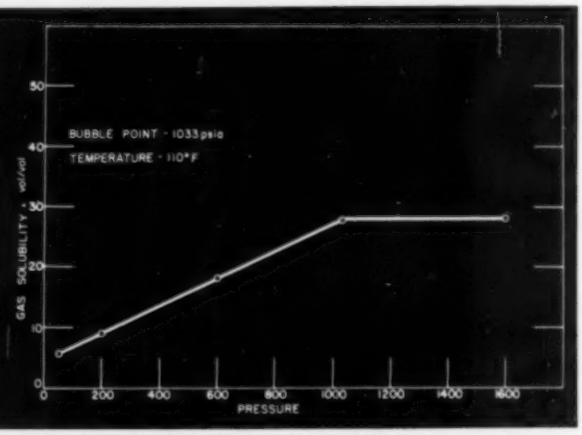

FIG. 3 — **Gas solubility** curve for synthetic crude oil-natural gas mixture.

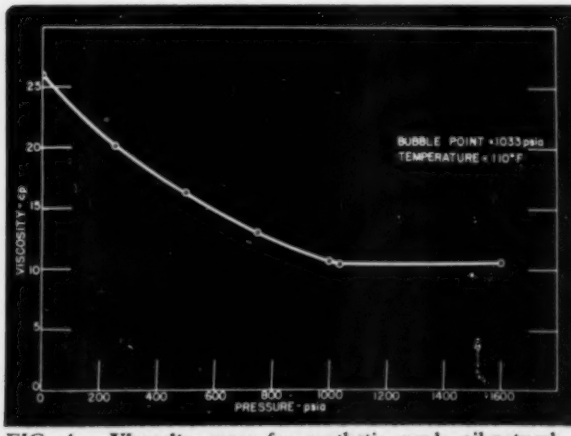

FIG. 4 — **Viscosity curve** for synthetic crude oil-natural gas mixture.

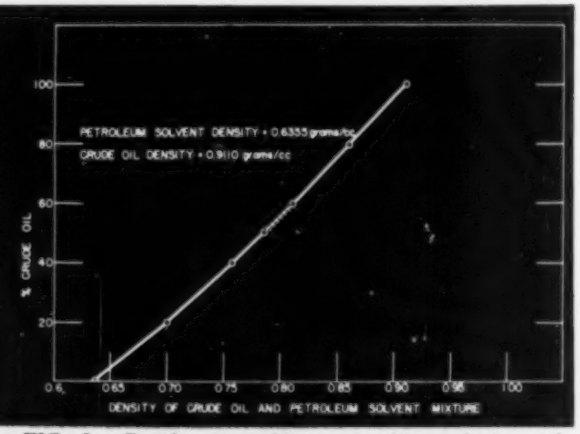
PETROLEUM SOLVENT DENSITY = 0.6355 grams/cc
CRUDE OIL DENSITY = 0.9110 grams/cc
% CRUDE OIL
DENSITY OF CRUDE OIL AND PETROLEUM SOLVENT MIXTURE

FIG. 5 — **Density-composition** curve for synthetic crude oil and petroleum solvent.

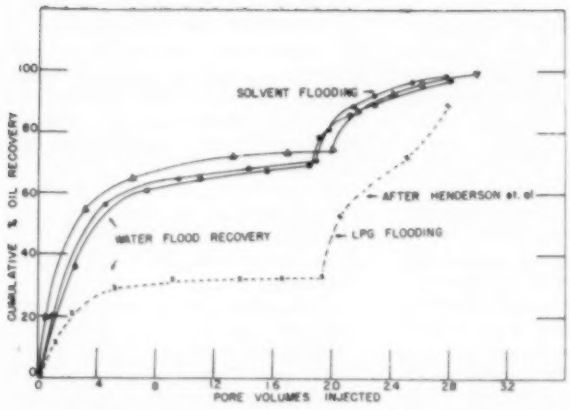

FIG. 6 — **Oil recovery** by waterflooding followed by miscible fluid flooding.

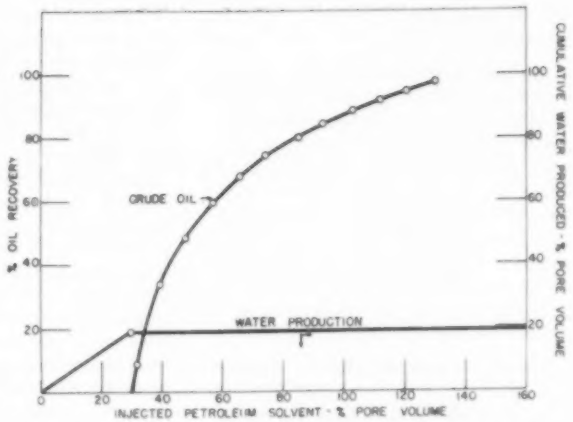
CRUDE OIL
WATER PRODUCTION
% OIL RECOVERY
CUMULATIVE WATER PRODUCED - % PORE VOLUME
INJECTED PETROLEUM SOLVENT - % PORE VOLUME

FIG. 7 — **Fluid production** after initiation of solvent flood.

This was accomplished in stages, so that equilibrium might be reached at the desired pressure. After primary depletion had been accomplished, the water flood was initiated on the core at a constant rate and constant pressure. When a produced water-oil ratio of 100-to-1 was reached, the water flood was discontinued, and crude oil solvent was pumped through the core at atmospheric pressure and at a rate of approximately 18.75 cc per min. Specific gravity of the effluent was determined in 25 cc increments until two pore volumes of petroleum ether had passed through the core. This was followed by compressed air for approximately two hours before evacuating the core.

Physical properties of the synthetic crude oil used in the study are indicated in Fig. 2, 3, and 4. Fig. 5 shows the effect of composition on the density of the petroleum solvent-crude oil mixture.

Results Encouraging

The data (Fig. 6) show that solution gas drive and waterflooding recovered nearly 70 percent of the oil initially present, and the solvent flood following the water flood recovered approximately 29 percent, leaving a residual oil saturation of only one percent. Henderson's, et al, waterflooding operation recovered about 35 percent of the oil originally present, and the LPG flood recovered an additional 60 percent of the oil leaving a residual oil saturation of approximately five percent. In both studies, approximately one pore volume of miscible fluid was injected to obtain the high recovery. The three upper curves (Fig. 6) bracket the data for three other runs which were not plotted to avoid congestion.

100 percent recovery indicated. The percentage crude oil recovery which may be obtained by flooding with petroleum solvent after waterflooding is shown by Fig. 7. Initially, 19 percent of a pore volume of water was produced before any crude oil production was observed. Oil recovery obtained by petroleum solvent injection of approximately 1.3 pore volumes was nearly 99 percent of the residual oil left after waterflooding the core to a 100-to-1 water-oil ratio.

By extrapolation of the oil recovery curve, the data indicate that substantially 100 percent crude oil recovery would have been realized by the injection of approximately 1.6 pore volumes of the petroleum solvent. This figure is representative of the six runs that were made. Initial water production ranged from 18.5 to 20.5 percent.

Oil in solvent. The percent crude oil in the effluent during the injection of the petroleum solvent for six separate runs is plotted in Fig. 8. Partial fractionation of this effluent would permit the use of the recycling technique suggested earlier. The effluent was approximately 50 percent solvent when 0.30 to 0.35 pore volumes of solvent had been injected. This means that by fractionation and recirculation, half of the injected solvent might come from the effluent when 0.3 to 0.35 pore volumes had been injected and 90 percent of the injected solvent might come from the effluent when 0.75 pore volumes had been injected.

Solvent make-up. The quantity of new or makeup petroleum solvent required in terms of percent of the solvent being injected may also be obtained by reading Fig. 8 directly. The total quantity of solvent required is equal to the area under the curve. For the conditions studied, the area under the curve is approximately 0.48 pore volumes indicating that by circulation

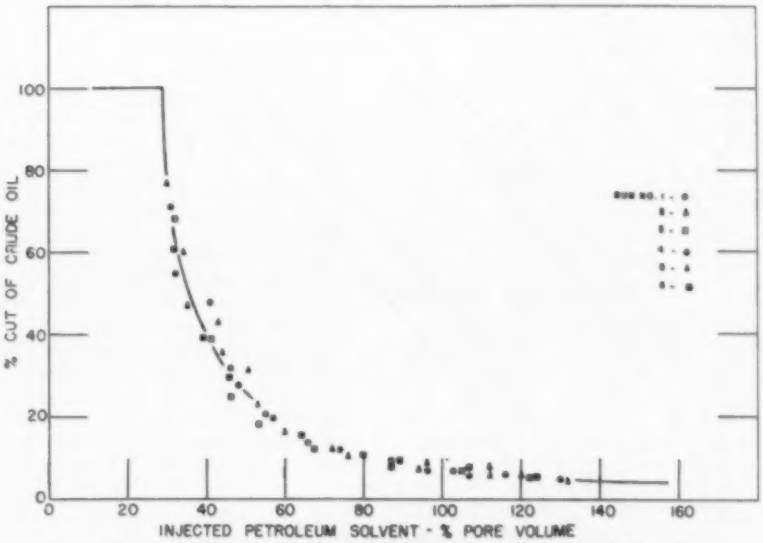

FIG. 8 — **Percent crude oil** in effluent for miscible fluid flooding.

only this quantity of material will be required.

Solvents. The miscible fluids which have been used for various laboratory experiments to increase the ultimate oil recovery have indicated propane, butane, petroleum ether, and kerosine. These are not the only solvents that may be used. Petroleum solvents as a class may permit the recovery of substantially 100 percent of the oil in place under conditions used in the laboratory, whether the solvent technique is applied before or after waterflooding.

Liquid or gaseous phase. Miscible fluid displacement after waterflooding may be conducted in either the liquid phase or the gaseous phase between the injection well and miscible fluid-crude oil transition zone. The quantity of miscible fluid which can be recovered after the application of the technique is an important economic consideration. In order to recover substantially all fluid, the material should be such that it could be readily recovered as vapor after the solvent flood. The selection of a suitable fluid would then permit the flood to be carried out with the miscible fluid and subsequently recovered as a gas.

If a liquid solvent is selected for the miscible phase flooding, the selection of a suitable solvent will depend largely on the solvent vapor pressure.

Fig. 9 is a plot of vapor pressure of the volatile hydrocarbons for reservoir temperature (100 F) would require a pressure at the flooding front of near 200 psia to maintain propane in the liquid phase. If butane were used, the pressure would need to be only 55 to 75 psia. During the recovery of the solvent, the shut-in reservoir pressure should approximate the vapor pressure of the solvent. During the recovery of the solvent, high vapor pressure would be desirable as this would permit a higher production rate.

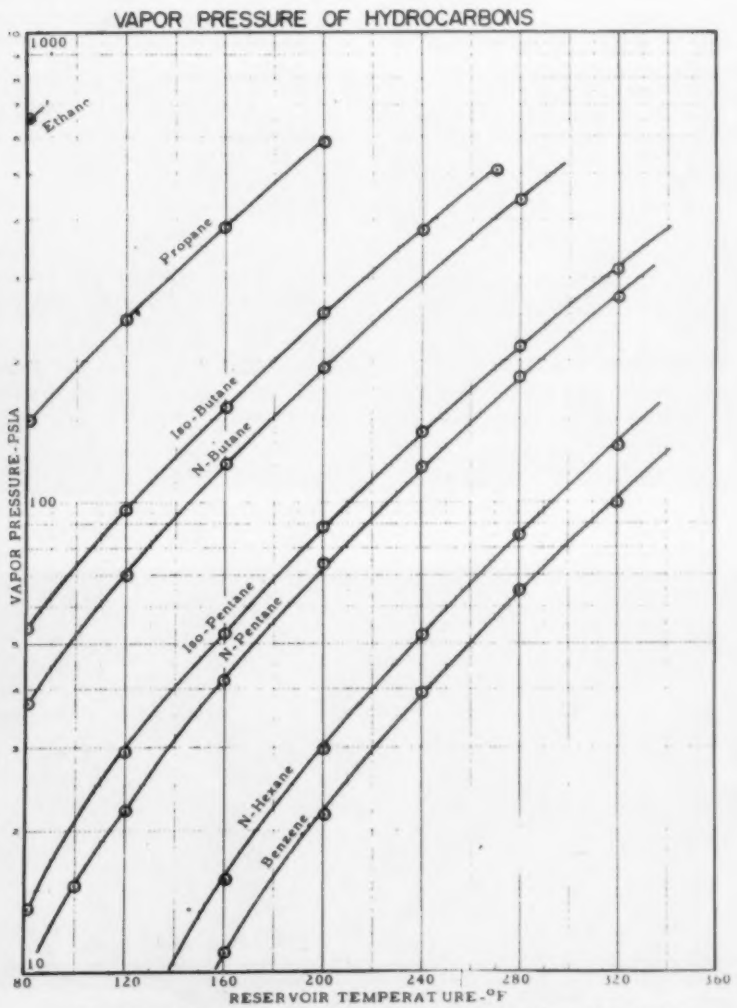

FIG. 9 — **Vapor pressures** of hydrocarbons at various temperatures.

Critical pressures and temperatures. Operation near the critical pressure of the miscible fluid requires special consideration. Although reservoir temperatures exceeding 206 F are above the critical temperature for propane, its use may permit a single phase miscible fluid drive between the injection well and the dry gas-liquid interface. The injection of propane followed by natural gas is still indicated to satisfy some of the requirements for miscible displacement.

Most cycling and gas injection projects now operate above the critical temperature and pressure of the injected gas. This provides a miscible fluid displacement up to the dry gas-wet gas interface; however, as the gas and liquid commingle, the critical pressure of the system rises rapidly and at reservoir temperatures between 150 to 300 F, the critical pressure may range from 500 to 10,000 psi for distillate to Mid-Continent crudes. Primarily for this reason ethane, propane, or butane is added to reduce the pressures required for miscible fluid displacement.

If the miscible fluid displacement is carried out in the liquid phase the evaporation of liquefied petroleum solvent in the reservoir will tend to lower the reservoir temperature. Temperature reductions may be expected to vary from near 5 to 15 F with the particular conditions.

Recovery and Recirculation

This laboratory study indicates that substantially all of the oil remaining in place after a water flood may possibly be recovered by flooding with a miscible fluid. By recirculation, considerable savings may be made in the quantity of miscible fluid required. For the conditions studied, although as much as 1.4 pore volumes of miscible fluid may be injected, only as little as 0.48 pore volumes may be required to accomplish this.

Acknowledgment

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When Pulling Tools from the Hole...

BLOWOUT CONTROL Begins Before They Occur

Knowledge of "pressure inversion" and "bubble" effects, and analysis of surface phenomena permits successful preventive control.

Homer N. Mead
Martin, Sykes and Associates, C. A.
Caracas, Venezuela

SERIOUS blowouts still happen. Some may be due to negligence but the majority take place while following accepted practices.

Gas and oil cut mud are often circulated through a choke after going in the hole following a test without the well blowing out. One seldom hears of these cases because they are usually accepted as normal procedure.

A slight change in conditions, mechanical failure, or human error might bring about a serious blowout. Why oil and gas enter the hole while pulling testing equipment, and the resulting effect should be explained and understood. The explanation given could apply to all cases where pulling equipment out of the hole is the reason for blowout, altogether the main emphasis in this paper will be on pulling testing tools.

This discussion is confined to blowouts in which there has been no lost circulation either prior to or after pulling the tester, and mud pressure *exceeds* reservoir pressure under static conditions. For clarity, some well operations have been generalized and averaged in the presentation.

Pressure Reduction

A cause for the reduction in pressure below any string of tools being pulled out of the hole is the actual upward movement of the string itself. Fig. 1 illustrates this fact. Fig. 1 is the general way in which pressure drop due to friction is shown. If a fluid is forced to flow through a tubular section of length L and diameter D_1 at a velocity V, the difference between P_1 and P_2 (after the weight of fluid is subtracted) is the pressure drop due to the movement of the fluid itself. If the tubular section moves upward at a velocity V (as shown in Fig. 1B) and the fluid characteristics and the diameter of the tubular section remain the same as in Fig. 1A, the pressure drop along length L will be the same. This pressure drop is a function of *relative* movement between the fluid and the surface enclosing it.

Fig. 1C and 1D show flow through an annulus. As in Fig. 1A and 1B, the pressure drop for a distance L due to friction will be the same whether either the fluid or the circular pipes are moving. The relative difference in velocity between the fluid and the wetted surface is the important thing. The hydraulic radius concept is used to calculate pressure drop in annular flow. It was devised so that pressure drop due to friction along wetted surfaces of odd shapes on which fluid moved could be referred to circular design. An "equivalent diameter" is determined which is used in equations of flow to calculate the pressure drop due to friction. The predictions made by using the hydraulic radius concept are surprisingly close to actual performance.

Fig. 1E and 1F show two other conditions. It is possible to move either the outer or the inner pipe alone. Obviously the drop in pressure due to friction in Fig. 1E could not be as great as in Fig. 1D. This is with identical fluids, equal diameters, length, etc. However, the pressure drop for Fig. 1E would always be greater than one-half the pressure drop in Fig. 1D. This is because the enclosing surface of the outer pipe is always more than one-half the total possible wetted surface. Fig. 1F would correspond to the condition of pulling a string of tools or a tester from a well. Under this condition the total pressure drop due to friction would always be less than one-half the pressure drop in Fig. 1D — with equivalent conditions. The wetted surface used in the hydraulic radius concept is only that surface on which there is a difference in velocity between it and the fluid. The equivalent diameter for Fig. 1F is

$$\frac{D_1^2}{D_2} - D_2.$$

Weight — Coming Out of the Hole

Consider the pulling of a string of tools from a well in another aspect. (Fig. 2.) Weight of the string on the hook when standing still is the weight of the string in air less the weight of the mud fluid it displaces. If the string is pulled up at such a velocity that the pressure in the mud at the bottom of the string is zero, the hook load will be the actual weight of the string plus the weight of the mud in the annulus.

As shown in Fig. 2, the difference in pull at the surface between hanging still in the hole and pulling at a velocity that will drop the fluid pressure to zero at the bottom of the string is the weight equivalent to the entire casing filled with mud to the depth in the hole where the bottom of the string is. Therefore, the increase in pull at the surface with increased velocity is directly related to the decrease in mud pressure at the bottom of the string of tools. This is assuming there is no acceleration of the string and that no friction exists between the string and the casing.

It is only necessary to know the amount of additional pull at the surface due to moving the string and the area of the casing to calculate the reduction in pressure at the bottom of the string. This increase in pull at the surface is the composite effect of friction and annular flow through any restriction in annular area. For example, 9⅝-in. casing has about 60 sq in. inside area. If the weight increases 12,000 lb at the surface at a certain upward velocity over what it was when the string was standing still, the reduction in pressure in the mud at the bottom of the string is about 200 psi.

Pressure Reduction

Two sample calculations are shown concerning this. Pressure drops were calculated using a hydraulic calculator and equivalent diameters using the formula shown on Fig. 1.

Example 1. In 9⅝-in. casing set at 9000 ft with 12 lb per gal mud in the hole, 8400 ft of 4½-in. 16.6 lb drill pipe and 600 ft of 6¾-in. OD drill collars are started off bottom at a hoisting speed of 30 sec per 90-ft stand.

*Presented before the Caracas Section of the AIME on May 14, 1957.

The reduction in pressure below the drill collars is calculated to be 50 psi. This should be considered minimum. High gel strength mud, plugged drill pipe, existence of mud ring, etc., would increase this pressure differential. The estimated additional pull at the surface for this reduction in pressure is 3000 lb.

Example 2. Seven inch casing is set at 9000 ft and the total depth of the hole is 12,000 ft. There is 11,400 ft of 3½-in. 15.5 lb drill pipe and 600 ft of 4¾-in. OD drill collars on bottom and the mud weight is 12 lb per gal. If this string is started out of the hole at a hoisting speed of 30 sec per 90-ft stand, the reduction in pressure below the drill collars will be approximately 175 psi. The estimated additional pull at the surface for this reduction in bottom-hole pressure is approximately 5300 lb.

As the drilling string is pulled out of the hole, it is possible that the hoisting speed may increase. If it does, then a greater differential in pressure could exist in the above samples than shown. The danger of fluid entering the hole from a potential blowout zone does not only exist when the string is close to bottom. It is theoretically possible to reduce pressure below the string as much as the entire weight of the column above that point. For example, in 10 lb per gal mud, it is possible to reduce bottom-hole pressure by 500 psi when the bottom of the string is at any well depth up to 965 ft from the surface. These data are submitted in order to show that a pressure drop of measurable proportions could occur simply by pulling out of the hole when a string of pipe is at almost any depth.

Pressure Reduction Causes

There are other related causes for pressure reduction when pulling testing equipment out of the hole. Some of these are:

1. The entire displaced volume must be filled by fluid from the annulus.
2. Rubber packers of the testing tool are, of necessity, nearly the same size as the hole or casing in which the tool must be set.
3. Most of the displacing fluid must pass from the annulus through the tester by means of a by-pass. The hydraulic radius of this by-pass is usually smaller than that of the annular space above the tester.

There are several other factors influencing blowout that should be mentioned. They are:

1. High viscosity, high gel strength mud.
2. Plugged by-pass by foreign elements in the mud.

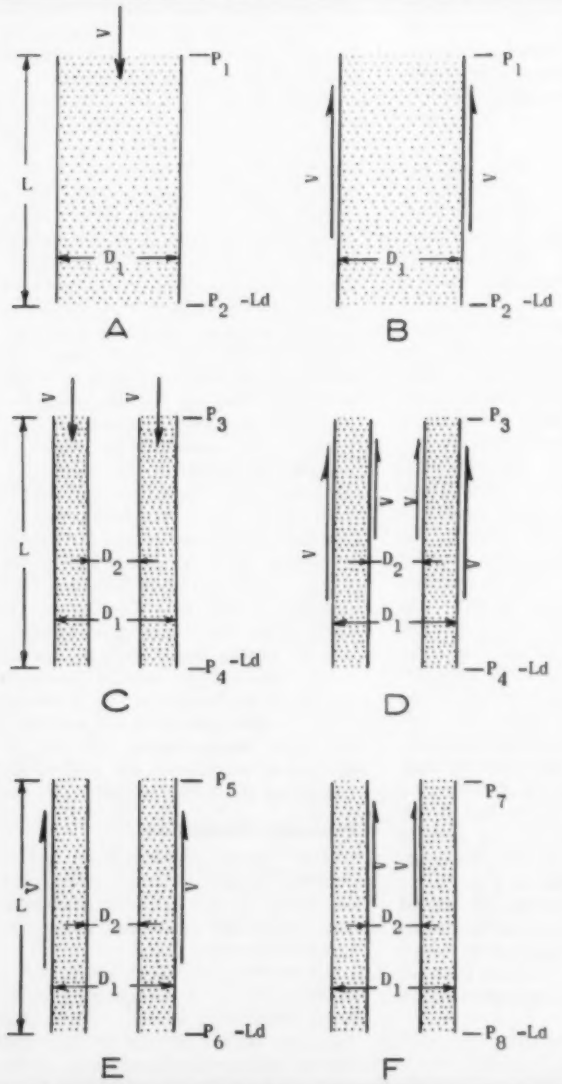


FIG. 1. **Pressure reduction** below the drilling string is partially due to actual upward movement of the string itself, when pulling pipe from the hole.

Hydraulic radius is $\frac{\text{Area}}{\text{Wetted perimeter}}$

For circle $\frac{\pi D_1^2}{4}$

Hyd. rad. is $\frac{\pi D_1^2}{\pi D_1}$ is $\frac{D_1}{4}$

Equiv. diam. is hyd. rad. X 4

Hyd. rad. is $\frac{\frac{\pi D_1^2 - \pi D_2^2}{4}}{\pi D_1 + \pi D_2}$ is $\frac{D_1 - D_2}{4}$

Equiv. diam. is $D_1 - D_2$

E

Hyd. rad. is $\frac{D_1}{4} - \frac{D_2^2}{4D_1}$

Equiv. diam. is $D_1 - \frac{D_2^2}{D_1}$

F

Hyd. rad. is $\frac{D_1^2}{4D_2} - \frac{D_2}{4}$

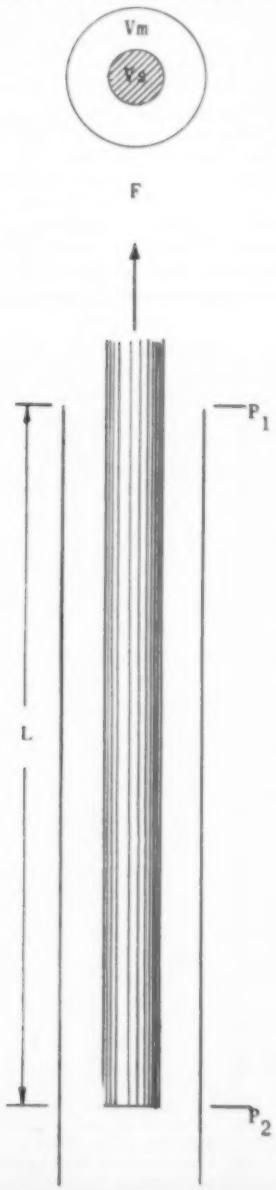
Equiv. diam. is $\frac{D_1^2}{D_2} - D_2$

3. Not keeping the annulus full when pulling out of the hole.

As suggested above, there are several reasons why the mud pressure below a tester may be reduced. It is entirely possible for a specific condition to exist in a well so that the mud pressure opposite a potential blowout zone below the tester will be less than the reservoir pressure of the zone when the tester is being pulled up the hole. Usually, if a mudcake has been formed across the reservoir face, the pressure inside the well must be lowered considerably below the reservoir pressure before fluid begins to enter the well. The pressure below reservoir pressure that the mud must drop to before flow into the well starts is usually an indication of productivity. The higher the productivity of the zone the less, usually, the differential in pressure that must exist prior to flow. In other words, a better well takes less differential below reservoir pressure before flow starts into the well.

The case just after testing a zone with a tester may be different. If the zone had been producing oil and/or gas on test, the space between the bottom of the tester and the producing zone will have been filled with hydrocarbon material. When the tester is pulled loose, the oil is again pushed back into the formation. A good mudcake, however, usually does not have a chance to form prior to the time the tester is pulled from the hole. In these cases, then, there is a strong possibility that when mud pressure is just less than reservoir pressure, flow will begin into the well.

FIG. 2. **Difference in "pull"** at the surface between hanging still in the hole and pulling at a velocity that will drop the fluid pressure to zero at the bottom of the string, is the weight equivalent to the entire casing filled with mud to the depth of the string in the hole.



V_m = Volume of annulus in cu ft per ft.

V_s = Volume of string in cu ft per ft.

W_m = Weight of mud in annulus in lb per cu ft.

W_s = Weight of string in lb per cu ft.

L = Length of string in ft.

P_1 = Pressure in psi at top (assumed to be zero).

P_2 = Pressure at depth L in the annulus in psi.

F = Force necessary to hold string in lb.

When string is hanging in hole without movement

$$F_1 = L\,V_s\,W_s - L\,V_s\,W_m$$

When string is pulled up at constant speed SO P_2 = zero

$$F_2 = L\,V_s\,W_s - L\,V_m\,W_m$$

Force necessary just to lift all of the fluid in the annulus and the string to depth L = $(F_2 - F_1)$

$$(F_2 - F_1) = L\,W_m\,(V_m + V_s)$$

Therefore,

The increase in pull at the surface to decrease the pressure in the mud at depth L from what is under static conditions to zero is equal to the area of the casing times the density of the mud in psi per foot of depth times the depth. Any increase in pull at the surface between these two extremes divided by the inside area of the casing in square inches will give the decrease in pressure at the bottom of the string in psi.

This does not take into consideration weight increase due to acceleration nor possible friction of string against the side of the hole.

Cases In Point

A hypothetical case may be taken for testing a given well, and data developed for both a high and low productivity zone. A general relationship between well productivity and the capability of the well to blow out is shown. Both of the examples have the same hole and hoisting conditions, as shown in Fig. 3. Also they have the same reservoir fluid. The only difference is in the productivity of the zones.

Reservoir A With a Reservoir Productivity Index to Oil of 30

Assume that a reservoir of 9000 ft has a productivity index of oil of 30. This will correspond to a stock tank productivity index to oil of approximately 16. The test has just been completed and the oil in the drill pipe has been circulated out. The first stand is being pulled out at a hoisting speed of 30 sec per 90-ft stand. At this velocity the pressure below the tester is reduced 400 psi. We shall assume that fluid is entering the hole from the formation. Under the assumptions that have been made, it will take about a 19,000 bbl-per-day rate to fill the space below the tester, as it is being pulled. Fluid is entering the formation at a rate of 3000 bbl per day so 3/19 of the 90 ft will be filled by the oil from below and 16/19 by mud from the annulus. The instant the string is stopped, there will be 14.2 ft of oil and 75.8 ft of mud in the 90 ft below the tester.

It is assumed that injectivity index is equal to productivity index for the blowout zone. The action of the nearly 300 psi of mud overburden will be to force the oil back into the formation as soon as the upward motion of the string has stopped. Under the stated assumptions this rate will be 9000 bbl per day or mud will go down the casing at a rate of 85.3 ft per min.

Since it takes 2 minutes on the average to break, rack and lower the elevators for the next stand, one would think that all the oil which came into the hole would be pushed back into the formation, especially since the oil flowed into the well at a differential of 100 psi and the overburden mud pressure is 300 psi. There is one condition which keeps this from happening. The

fluid from the reservoir is different, lighter, and usually insoluble in the drilling fluid. There will be a tendency for the slug of reservoir fluid to move up the hole, by-passing the mud above it.

In the analysis of this hypothetical case it is assumed that the slug of reservoir fluid moves upward at a relative speed to the mud of 20 ft per min. It is also assumed that all the reservoir fluid comes out of the very top of the reservoir and when the mud once again travels downward and covers the top of the reservoir zone, the flow into the reservoir will stop.

Looking at Fig. 4A, the condition is shown as that point in time when the first stand has been pulled up 90 ft and just set in the slips. Immediately the mud begins to flow down the hole at a displacement rate of 85.3 ft per min and the oil moves up through the mud at a rate of 20 ft per min. The amount of the oil slug which still theoretically remains in the casing when the mud hits the top of the reservoir is 20/85.3 times 14.2 ft or 3.33 ft. This condition is shown in Fig. 4B and 4C. Approximately 15 sec of the remaining 2 minutes until the next stand started out of the hole has passed leaving 1¾ minutes and the mud has reached the top of the reservoir and sealed off flow downward. Immediately the 3.33 ft oil slug starts up the hole at a rate of 20 ft per min. When the bottom of the oil slug is 35 ft above top of the perforations, the next stand is started out of the hole. The overburden pressure has been decreased 0.66 psi by the first slug so a little more oil comes in. When the second stand has been pulled out and the mud once again starts downward, a slightly larger oil slug remains to start its upward journey. The length of this oil slug is 3.41 ft and the top of this second slug is about 35 ft below the bottom of the first slug.

FIG. 3. ASSUMPTIONS FOR HYPOTHETICAL CASES

Hoisting conditions

1. 9⅝-in. Hookwall packer on 4½-in., 16.6 lb drill pipe.
2. Hoisting speed is 30 seconds per 90-ft stand.
3. Reduction in pressure below packer when pulling each stand is 400 psi.
4. Average time per stand is 2½ minutes.

Hole conditions

1. Formation tested through perforations 9000-9030 ft.
2. 9⅝-in. casing.
3. 10 lb per gal mud — density of .519 psi per ft of depth.
4. Mud pressure at 9000 ft is 4670 psi.
5. Static reservoir pressure at 9000 ft is 4370 psi.
6. Oil slugs will move through the mud at a constant velocity of 20 ft per min.

Reservoir fluid

1. Stock tank oil gravity is 40 deg API.
2. Solubility is 1500 cu ft per bbl.
3. Formation volume factor is 1.9.
4. Gradient of reservoir fluid in hole is .319 psi per ft of depth.

Fluid Loss

A condition has now been set up where the overburden pressure becomes less and less and the size of the slugs becomes gradually larger. Fig. 5 shows what happens and also shows about how far up the first slug is when the entire string has been pulled out of the hole. Under the assumptions set up, there will be 100 slugs increasing gradually in size from 3.35 ft to about 12.5 ft in a downward direction. The top slug will be at about 4500 ft and the entire group will be moving upward through the mud at a rate of 20 ft per min. The total length of all the oil slugs together will be about 650 ft of reservoir oil volume or about 690 ft when the gas expansibility due to reduction in pressure on the slugs is taken into account at the time the last stand is pulled from the hole. It is assumed that the string will be pulled wet, and that, on the average, just ⅗ of the mud in each stand will have gone through the holes in the circulation joint before breaking out the stand. There will be then 0.43 bbl of mud spilled on the floor with each disconnection. The pulling of 100 stands will mean that 43 bbl of mud will have been spilled on the floor. The displacement of 9000 ft of 4½-in. drill pipe is 49 bbl. The total amount of mud needed to replace the volume of the drill pipe and the mud spilled on the floor will be 92 bbl. The fluid entering from below will occupy 51 bbl when the last stand is pulled. The level in the mud pit will, therefore have gone down. If the mud pit is 8 ft by 20 ft, the pit level would have dropped about 1½ ft. On the face of it, it would appear from surface conditions that everything is fine and that no dangerous series of events had taken place.

The static load on the hook after the tester has been pulled loose and the fluid inside the drill pipe circulated out is about 126,000 lb. In order to have 400 psi reduction in pressure at the bottom of the tester when pulling, it would have been necessary to pull

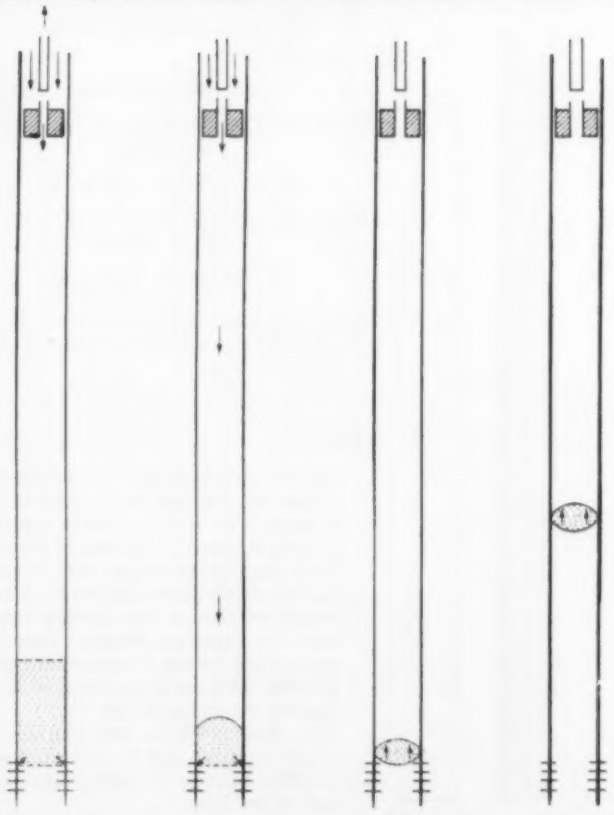


FIG. 4. **Oil slug**, entering the hole as pipe is being pulled, is shown here in its 20 ft per min upward travel. When a 90 ft stand has been pulled and slips have been set, mud begins its downflow at a displacement rate of 85.3 ft per min. The oil slug, measuring 3.33 ft in length, will travel 35 ft before the second stand is pulled.

out the first stand at 150,000 lb. This is neglecting any force due to acceleration or any frictional force of the testing string on the sides of the casing. Each succeeding stand would be pulled with a force 24,000 in excess to the dead weight of the stands remaining in the well. The pressure of the mud column when the last stand has been pulled is still 150 psi greater than the reservoir pressure. It would appear at that time, therefore, that this well will not blow out. This will be discussed further after presenting the next example.

Reservoir B with a Reservoir Productivity Index 2

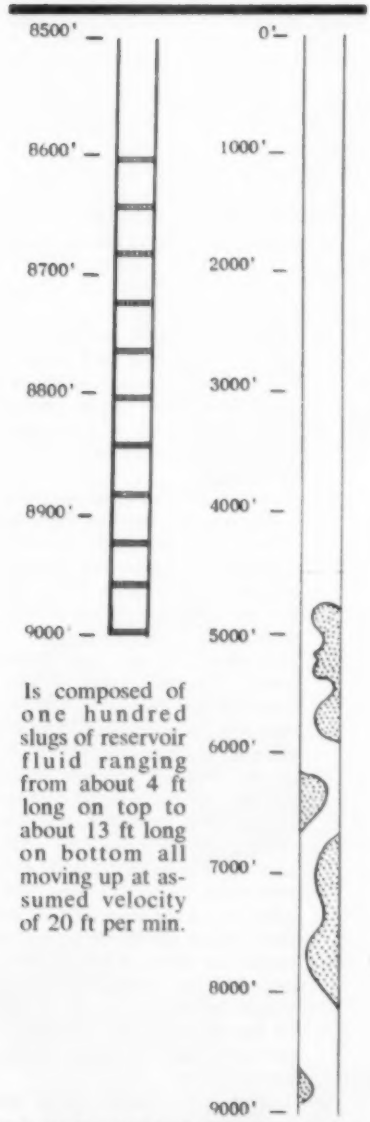


FIG. 5. **One hundred oil slugs,** from 3.33 to 12.5 ft in length, enter the hole by the time complete string has been pulled. Top slug will be at about 4500 ft. This is at an assumed upward velocity of 20 ft per min.

Assume that all conditions remain the same as for the first example except that the productivity index to oil of the reservoir fluid is 2 instead of 30. This will correspond to a stock tank productivity index to oil of 1.05. Under these conditions the slug of reservoir fluid that will come in the hole in pulling the first stand will be 0.95 ft. With a drawdown of 100 psi, the reservoir will contribute just at a 200 bbl-per-day rate or 200/19,000ths of 90 ft. This is 0.95-ft fill. In this case, however, the 300 psi of overburden mud pressure will cause mud to flow down the hole at the rate of 3 ft per min. Since the oil slug is moving up past the mud at a speed of 20 ft per min, the whole slug will tend to move up the hole. In this case the total influx of reservoir fluid caused by pulling out of the hole will amount to 100 slugs, each about 1 ft in length. These 100 slugs will be fairly evenly distributed in the lower 4500 ft of hole. The lower 4500 ft of mud in the hole will thus be contaminated with oil but not enough fluid has come in from the reservoir to cause a dangerous condition. Of course, this oil and its associated gas will tend to continue to move up the hole, but such a small quantity could largely be absorbed in the mud itself.

These facts would indicate that the better the well the more hazardous the testing operation. It could also indicate the rotary crews, used to testing operation in low productivity areas, could get into serious trouble if techniques of testing that proved adequate there were put into operation in areas of high productivity. Productivity of the well is a definite factor that should be taken into account in testing procedure.

Returning to Reservoir A, the last stand has been pulled from the hole. The mud pit has been examined and the fluid level has dropped about 1½ ft. The hole stands full. One hundred slugs of oil and its associated gas are in the mud column in the hole from 9000 ft to 4500 ft and all are moving up at a speed of 20 ft per min. The oil slugs are increasing in volume as they move upward. When the top slug is at 4500 ft and the bottom one is at 9000 ft, the total volume is increasing at about 1 ft of casing volume every minute. Such an increase might not be noticed for some time.

Bubble Effect

Two other concepts include the "bubble effect" and the "inversion of pressure effect."

A bubble of expansible fluid that is lighter than the mud will tend to bypass the mud on its upward journey until it reaches a point where the decrease in pressure due to its expansion is less than the decrease in pressure of the displaced mud column above it. At that point it will blow the mud out of the hole. Fig. 6 will show this better. For illustrative purposes it is assumed that the slug G is gas with no weight. In Fig. 6A the slug is at such a depth that if it doubled its volume thereby halving its pressure, the pressure in the mud column above would not be decreased by one-half. At this depth then

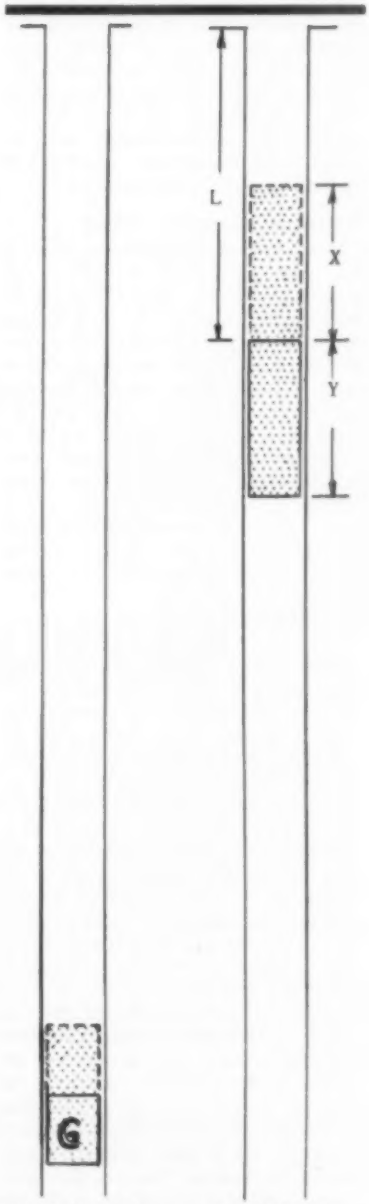


FIG. 6. **Slug G** represents a bubble of expansible fluid lighter than the mud in the hole. It is assumed here that G, having no weight, will double its volume (in A) and thus reduce its pressure by one-half. But at point L (in B) the slug will be at a critical point, where the pressure decrease by doubling its volume will just equal the drop in pressure of the mud column above. When the slug reaches this point, it will begin to lift the overburden of mud from the hole.

the slug will continue upward by by-passing the mud. At a point L, however, the slug G will be at a place in its upward path where the pressure decrease by doubling its volume will just equal the drop in pressure of the mud column above. This is a critical point. When the slug reaches this point it will begin to lift the overburden of mud from the hole. Oil with its associated gas is, of course, not as expansible as gas alone, varying in degree with the solubility and amount of free gas present. In general it may be said that the well is at a critical stage in immediate danger of blowing out when the top of the slug is approximately twice its length from the surface regardless of the mud weight of the column.

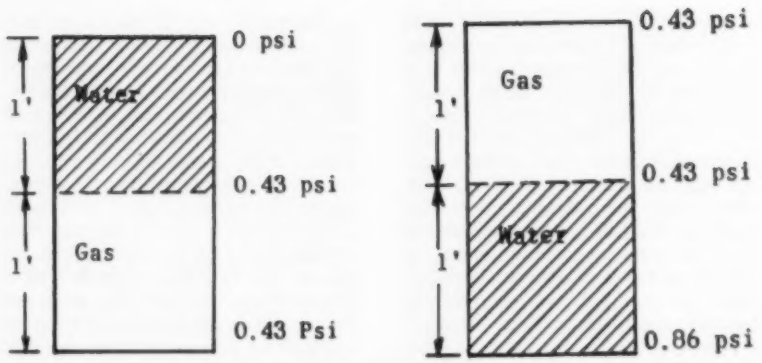


FIG. 7. **Pressure inversion effect** is illustrated by these two 1-ft cubes of water and gas. The pressure changes shown here are facts which make this concept possible. Assume that the gas in A has entered the hole and the well is immediately shut in. There is no pressure at the surface, but as the gas rises through mud in the hole, the pressure at the top of the hole rises.

Pressure Inversion Effect

The inversion of pressure effect is one that has rather widespread acceptance and has been discussed by both engineers and toolpushers in several different ways. Looking at Fig. 7A, if it were possible to balance 1 cu ft of water on 1 cu ft of gas, the pressure on the gas would be .43 psi and the pressure of the gas would be .43 psi — if gas had no weight. Now let us invert it. If the *volume* of 2 cu ft remains unchanged, the pressure of the gas is still .43 psi. The condition now existing, however, is that there is a pressure of .43 psi on top and 86 psi on the bottom. This is a fact.

Now look at a well with this concept in mind. If fluid from Reservoir A comes in the well and the well is immediately shut in, the pressure at the surface will begin to rise. If the reservoir face does not break down with increased pressure and there are no leaks at the surface or at any intermediate point, the rate of increase in pressure at the surface will be directly related to the speed the slug is moving up the hole. Under the assumption set up for Reservoir A, the slug would by-pass the mud at a speed of 20 ft per min; therefore, the rate of increase in surface pressure would be approximately 10 psi per min.

It should be remembered that the inversion of pressure effect is additive no matter what extra pressure is imposed at the surface — provided the volume remains constant and the slug of hydrocarbon material is compressible. If the higher pressure breaks down the reservoir face and fluid goes away there or if leaks occur at the surface or any intermediate point, the inversion of pressure effect will be reduced by the amount that the volume is increased.

Fig. 8 will help to explain this. In Fig. 8A a quantity of reservoir gas comes into the hole and then the mud again comes down over the face of the reservoir and flow out into the reservoir is stopped. If the volume of the entire mud column including the gas slug remains constant, the gas slug will always have a pressure of 4000 psi (except for the pressure change due to change in temperature). In Fig. 8B the slug is shown one-half way to the surface. At that time the pressure is still 4000 psi. However, at this time the surface pressure has increased to 2000 psi and the bottom-hole pressure to 6000 psi. Assume the surface pressure is increased to 4000 psi by pumping in a small quantity of mud fluid. The pressure on the gas is now 6000 psi. As the slug continues to go upward, the pressure at the surface will increase to 6000 psi.

This will help explain a phenomenon that occasionally happens. Assume that a well starts to blow out, the blowout preventers are closed and the surface pressure goes up to 8000 psi. Assume than an attempt is made to circulate through a choke at 1200 psi. Later, circulation is stopped and the pressure remains at approximately 1200 psi. This would be logical according to the inversion of pressure effect.

It is possible now to look back on Reservoir A and realize that a dangerous chain of events has occurred with the possibility that a blowout will take place in the next few hours. This blowout could have occurred following the usual existing procedures for pulling testers from holes. The hole was kept full and took fluid all of the time the string was being pulled from the well.

In actual practice it is customary to pull the first few stands out at very low speed. As soon as it is established the hole is taking fluid and other indications are that all is well, the speed of pulling out is increased. When the entire testing string has been pulled, the bottom few thousand feet of hole may contain slugs of reservoir fluid that are probably hours away from the critical point where the well is in immediate danger of blowing out. The assumption of constant speed for the entire string was made for ease of presentation. It is realized that constant hoisting speed for pulling an entire testing string is not usual practice.

Recommended Procedure

With these data and observations in mind a recommended procedure for pulling a tester out of the hole will be presented.

1. After testing tool is pulled loose, and the tubing or drill pipe is bled down, circulate out the remaining material in the testing string (presuming a circulatory valve has been installed above the tester).
2. Know or calculate how much the overburden pressure of the mud column exceeds the reservoir pressure. If this is not known, estimate a safe figure. Calculate the area of the casing or the drilled hole in square inches.
3. Pull up in low low and notice how much the string weighs. Then do not pull at a velocity that will increase the weight on the hook to more than the weight of the string at the low speed plus the amount the mud column exceeds the reservoir pressure times the hole area. This addition should be decreased with experience with increased productivity of the reservoir. At no time during the entire period in which the string is being pulled out of the hole should the pulling weight be more than the weight of the string left in the hole *at that time*, plus the added weight factor.
4. Just prior to coming out of the hole, measure the mud pit that is to supply the mud to keep the annulus full. Calculate how much the fluid level will drop in the mud pit per 10 stands pulled

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and measure the drop after pulling each 10 stands to be sure there is no fluid coming in from the bottom. Be sure that all fluid spilled on the floor when breaking out stands is accounted for—at least in an overall fashion. Fluid inside the testing string would not be measured if no circulation valve is in the string.

5. If, at one of the times the pit is measured, it appears that fluid is coming in from the reservoir, close the blowout preventers and put a valve on the drill string. Check to see if the pressure increases in both the annulus and testing string. Keep the BOP's closed for at least 15 minutes. Note any pressure increase in minutes. This pressure increase per minute divided by the mud gradient in psi per foot will give the rate at which the slug of oil or gas is moving up from bottom. It will also tell whether or not there is any fluid in the hole that has come in from the reservoir because the surface pressure will not increase if no fluid has come in from bottom. If fluid has come in from below, the decision whether or not to continue pulling out of the hole will depend: (1) Upon how much fluid is estimated to have entered the hole from the reservoir, (2) upon decision of well site supervisors.
6. These recommendations are in addition to all other safety rules and procedures that the company may have.

The above procedure may be employed for any string being pulled out of the hole. The loss in pressure at the bottom of the string with increased pulling weight at the surface due to increased lifting speed of the string is true for any string of tools being pulled. Care must be taken, to be sure, that the indicated difference does not include friction between the hole wall and the pipe. If there is such friction it should also be accounted for. The possibility of this friction should suggest that the testing string be pulled up at very low speeds to determine the initial weight.

The productivity of the well is a most important factor. Under similar conditions an extremely high productivity well will blowout when a well of low or medium productivity will not be affected in any way. Probably the greatest danger occurs when drilling personnel that have operated in the areas of low productivity move to areas of high productivity. They will tend to follow the same testing practices they have used in low productivity areas. This can prove disastrous. Probably one of the most dangerous practices they will continue to use will be that of filling the annulus every 5 to 10 stands. In areas of low productivity this will not jeopardize the well. In areas of high productivity this might provide that extra lightening of mud pressure necessity to bring reservoir fluid into the hole. One of the reasons advanced for filling up the annulus after pulling 5 or 10 stands is that one is better able to observe whether or not the well is coming in.

This is debatable on two counts. First, if hydrocarbon material is coming in from bottom, it will take a long time before the reservoir fluid will rise to a depth where it will blow the mud out of the hole. Before that time the rate of volume increase will be slow and could not be noticed at all if the annular fluid level were down hole. If the hole is kept full at all times and the mud pit level is measured every 5 or 10 stands, much better control will be had. Also maximum mud pressure will be kept against the formation and, after all, it is reduction in mud pressure that causes reservoir fluid to enter the well bore.

Secondly, if there is gas leakage during a test from tubing collars or drilling threads, there certainly can be no control when the mud level in the annulus is at some indeterminate place below the surface where it cannot be seen. Of course, the possibility does exist that a slug of gas will have leaked into the annulus. It is suggested that after the first stand is pulled — thereby breaking the mud gel, the blowout preventers be closed against the string to note any pressure rise. If there is no pressure rise, there is no compressible fluid coming up the annulus. Any method that is not necessary which reduces pressure against the formation should be avoided.

Thus, in deep wells the critical point at which the well is in immediate danger of blowing out will be hours *after* the tester has been pulled from the hole. Conditions under which fluid comes in from reservoir usually occur hours *before* the actual blowout.

Blowouts caused by pulling a testing or drilling string from wells *can* be prevented by proper observance and evaluation of surface conditions. ★ ★ ★

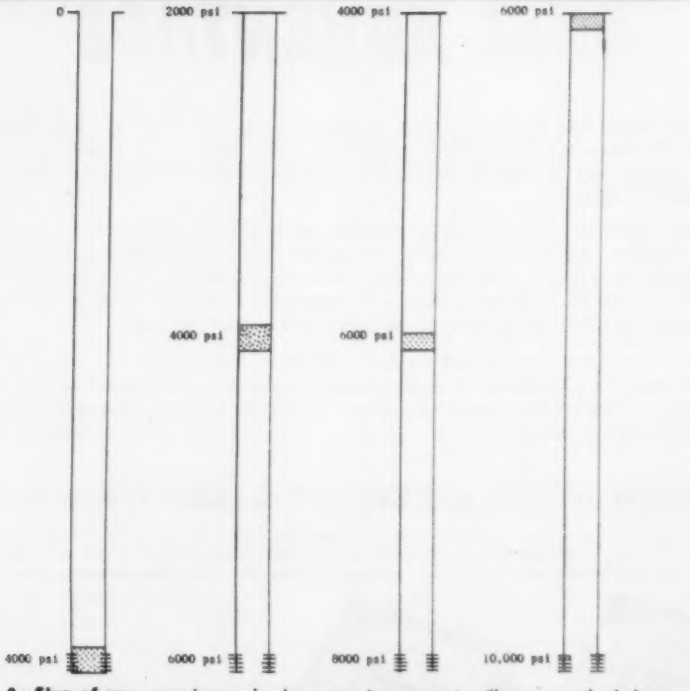

FIG. 8. Slug of gas, assuming mud volume remains constant, will move up the hole, and will keep its pressure of 4000 psi. If, however, additional mud is pumped in and surface pressure is increased from 2000 psi to 4000 psi by pumping in a small quantity of mud, the slug will be compressed and its pressure will increase from 4000 psi to 6000 psi. The slug will continue its upward movement and as it nears the top, well will blowout.

The Author

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He is a graduate of the University of California, and in 1939 joined the Union Oil Company, working for that company until 1946. He then was employed by Venezuelan Atlantic Refining Company, working in Venezuela until August 1955. He later joined Aramco, working in Saudi Arabia as senior reservoir engineer. He returned to Venezuela in November 1956 to take his present position.

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The Magnolia field is located in Columbia County, Arkansas, about six miles east of the town after which it was named.

Unusual Magnolia Field WATERFLOOD PLAN

Unitization provided the key that will unlock an estimated 31 million additional bbl of oil from several Smackover zones in this southern Arkansas field

S. W. Kingsbury,
The Atlantic Refining Company, Dallas, Texas

FOUR years of intensive effort were required to bring about unitization of the Smackover lime reservoir in Magnolia field, Columbia County, Arkansas. The benefits resulting from that effort are now being realized.

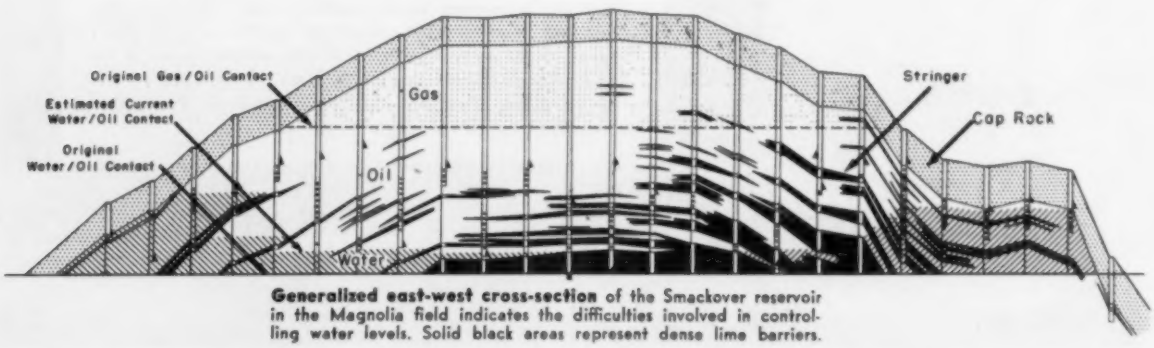
Unitized operations were commenced in April 1956 with The Atlantic Refining Company as unit operator. Since that time, remarkable improvements in producing performance have been achieved through selective production of the more efficient wells. This increased producing efficiency is an immediate benefit of unitization which represents substantial savings in operating costs and conservation of reservoir energy.

Under the program which is now being adopted, the long range benefit of unitized operation will be the recovery of 31,000,000 more bbl of oil and condensate than the estimated ultimate recovery without unitization.

The most unusual feature of the Magnolia Unit project is that the unitized plan requires an extreme degree of control over water-oil contact and gas-oil contact positions and movement in the reservoir. An extensive well workover program has been undertaken to provide a means of controlling these fluid contacts. The workover program is designed to establish a new system of water injection wells, producing wells and make-up water supply wells for the unit.

The history of Magnolia field differs from that of most unitization projects because a program of water injection into the Smackover formation was conducted for more than eleven years before the field was unitized. In excess of 64,000,000 bbl of water were injected prior to unitization in four peripheral injection wells.

The non-unitized water injection program substantially reduced the rate of reservoir pressure decline. Pressure maintenance was not the only problem facing the field operations, however. Another more difficult problem was uneven movement of water into the



Generalized east-west cross-section of the Smackover reservoir in the Magnolia field indicates the difficulties involved in controlling water levels. Solid black areas represent dense lime barriers.

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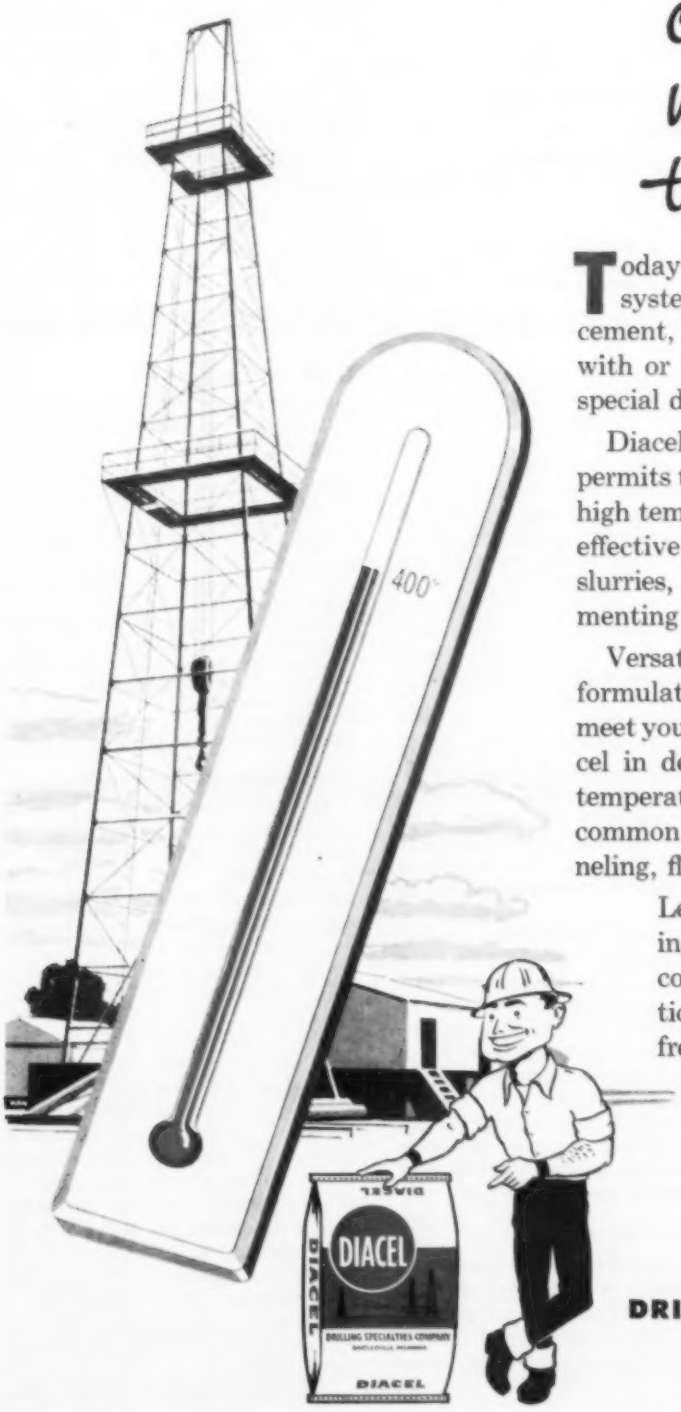

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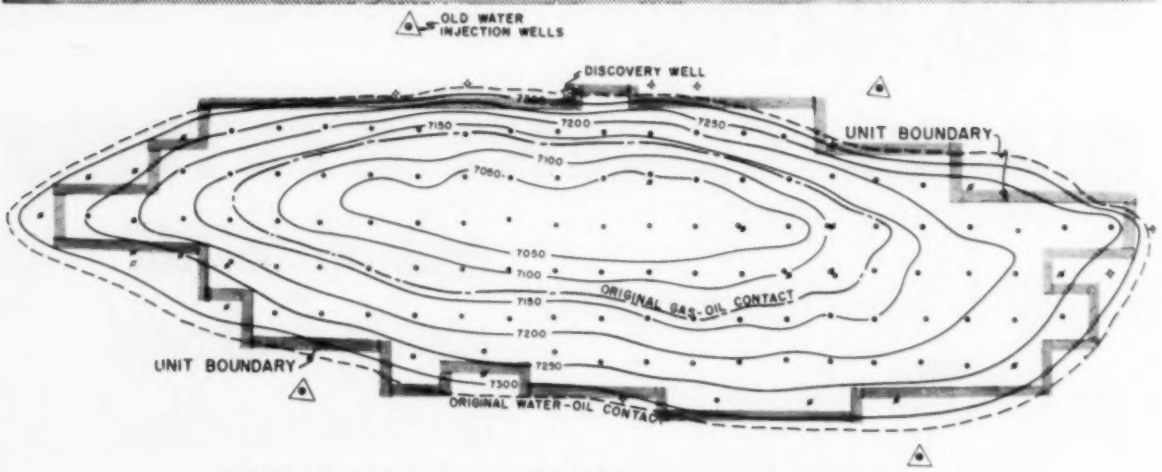

FIG. 1. **Structure map on top of Smackover** lime porosity showing discovery well, estimated original fluid contacts, unit boundary and the water injection wells of the cooperative pressure maintenance program conducted prior to unitization.

oil reservoir. Working within the inherent limitations of competitive operation, no satisfactory method could be found to correct the non-uniform water influx into the field. This situation caused the operators to realize that unitization would offer the only practical means of revising the water injection system and continuing to inject without endangering correlative rights.

Unitization studies were commenced in February 1952. Slightly more than four years later, in March 1956, the proposal to unitize the Smackover lime formation of Magnolia field was presented to the Arkansas Oil and Gas Commission. The Commission approved the project and ordered unit operations to be commenced on April 1, 1956.

History and Reservoir Data

Magnolia field is located in southwestern Arkansas near the town of Magnolia. The field was discovered in 1938 when the Kerr-Lynn Oil Company completed their J. M. Barnett No. 1 in the oolitic Reynolds member of the Smackover limestone on the extreme north edge of the field as indicated in Fig. 1.

Development proceeded on 40-acre spacing and was essentially complete by January 1942 when a total of 116 producing wells had been drilled. The average producing depth of Smackover wells in this field is 7500 ft.

Geology

The Smackover structure of Magnolia field was found as a result of geological studies of surface outcrops, early shallow wells drilled in the area and seismograph work done in 1935 and 1936. Subsequent development showed the structure to be an uncomplicated anticline six miles long and one and one-half miles wide (as shown in Fig. 1). This structure covers an area of about 4300 acres and has a structural relief of about 300 ft.

Initially, the Smackover pool had an oil zone with a maximum thickness of 185 ft and was overlain by a gas cap with a maximum thickness of 106 ft. The original water-oil contact was found at a depth of about 7323 ft subsea, and the original gas-oil contact was located at about 7138 ft subsea.

Rock Properties

Almost 11,000 ft of net Smackover pay formation were penetrated in drilling the producing wells in the field. Core analyses were run on about 3700 ft of this net pay providing a large amount of core data in comparison to that available in most fields as old as Magnolia.

Porosity and permeability development vary greatly throughout the reservoir. Generally, the formation is more uniform and of better quality in the upper 100 ft of the Smackover section. Overall average porosity of net pay is about 16.5 percent while permeability of net pay throughout the reservoir arithmetically averages about 1100 md. The average connate water saturation of the reservoir is estimated to be about 30 percent of total pore volume.

Reservoir Content

It is estimated that the original in-place contents of the Smackover reservoir were: 288,000,000 bbl of stock tank oil, 249,000,000 Mcf of solution gas and 107,589,000 Mcf of gas in the gas zone.

Fluid Characteristics

Properties of Smackover reservoir oil at initial conditions were determined to be:

Reservoir temperature	207 F
Initial reservoir pressure (at datum of 7200 ft subsea)	3495 psig
Saturation pressure	Saturated at initial pressure
Initial solution gas-oil ratio:	864 Scf/STBO
Formation volume factor at initial pressure	1.479 RVB/STBO
Viscosity of saturated crude at initial reservoir conditions	0.47 centipoise
Gravity of stock tank oil	39° API

Early Field Performance

The Smackover reservoir of Magnolia field has had a limited amount of natural water influx throughout its producing life. This natural water movement into the reservoir, however, has not been sufficient to replace the voidage caused by production. As a result, reservoir pressure began dropping sharply soon after the field was discovered.

The Arkansas Oil and Gas Commission and the various field operators were alarmed by the rapid decline in pressure early in the life of the field. It was realized that a continued pressure drop would change the method of oil recovery from a water drive to less efficient recovery methods (predominantly a combination of gas cap expansion and solution gas drive). These less efficient types of recovery mechanisms could have cut the ultimate oil recovery of the field to half, or less than half of what it would be with continued water drive.

The field operators closely coop-

erated with the Arkansas Oil and Gas Commission to find the best means of preventing further reservoir pressure drop. First, the Commission reduced the oil allowable of the field. Then, severe restrictions were placed on excess gas and water production. However, these reductions in the rate of withdrawal were still not enough to stop the decline in field pressure.

Cooperative Water Injection System

The withdrawal limitations established by the Commission (which developed out of a series of meetings between the field operators and the Commission) helped to band virtually all the working interests together into the formation of the Magnolia Pressure Maintenance and Salt Water Disposal System. Through this voluntary organization, the operators initially spent more than $600,000 in drilling four water injection wells and providing the surface facilities necessary to return all the produced water to the formation together with make-up water from the shallow Sparta formation. These four peripheral injection wells were drilled in a quadrant pattern outside the original producing limits of the field. Consequently, the wells were completed for injection below the original water-oil contact of the reservoir.

Water injection was commenced in January 1945. By October of 1946, the Arkansas Oil and Gas Commission was assured that the injection system was operating in a satisfactory manner. Accordingly, the Commission relaxed the severe water penalty limit which had been imposed three years before.

During the period from 1938 to 1945, before injection was started, about 65,000 bbl of oil were produced for each pound of reservoir pressure drop. From 1945 until unitization in 1956, with the cooperative injection system in operation, about 180,000 bbl of oil were produced for each pound of drop in reservoir pressure.

The system of four injection wells was designed to supplement, not to change, the natural water influx. However, after the injection system had been in operation for a few years, the operators saw that a serious problem was developing. Both the natural water influx and the injected water were moving primarily into the upper portion of the oil reservoir because of the much better permeability development in that part of the formation. Consequently, the lower zones and the central portion of the field were experiencing very slow rates of water level rise in comparison with the rapid water-oil contact movement in the upper zones on the flanks. The operators realized that this situation, if not corrected in time, could cause the water to override the oil and trap it in the lower portions of the reservoir resulting in much more expensive operations and placing considerable oil reserves in jeopardy.

Members of the pressure maintenance system worked diligently to develop a method of balancing water injection which would offset the uneven movement of water into the field. They were unable to devise a plan acceptable to all of the operators. Either continuing injection on a competitive basis or

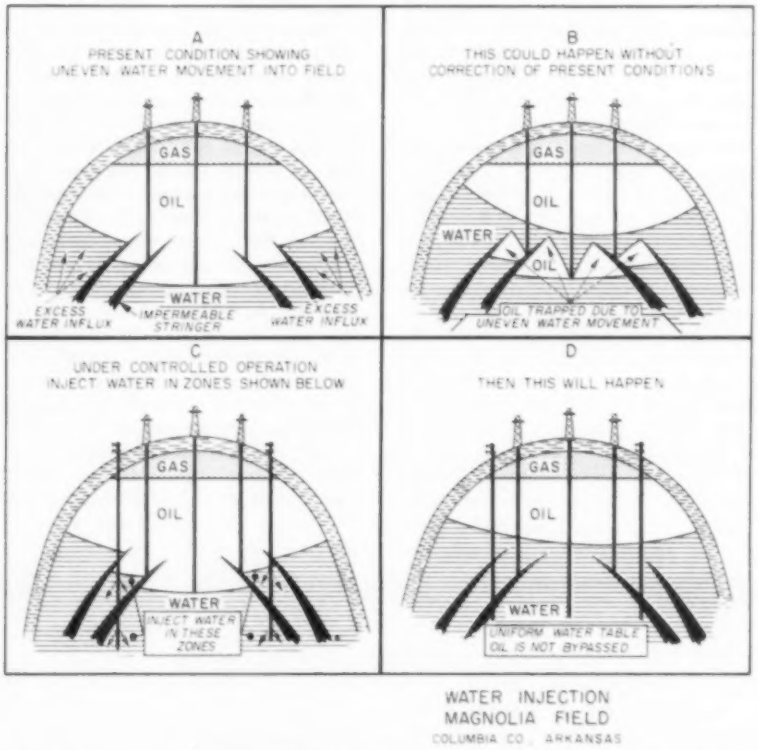

FIG. 2. **Uneven water entry problem** and method being used to level water-oil contacts as shown by a series of four idealized cross-sections.

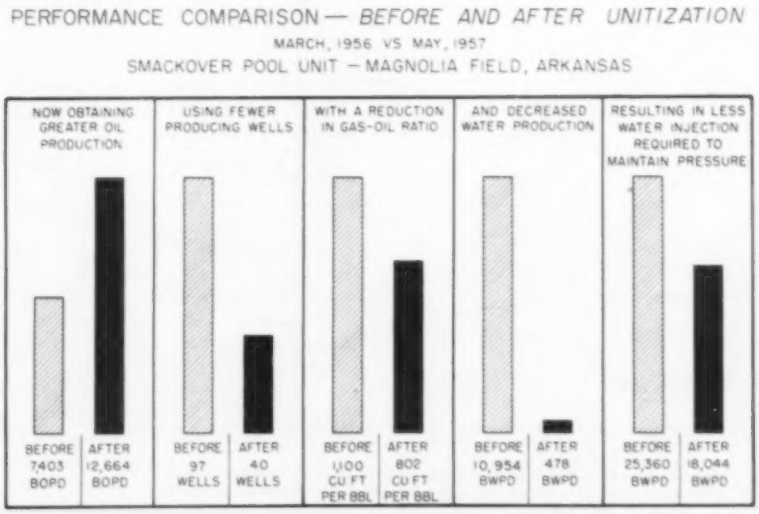
PERFORMANCE COMPARISON — BEFORE AND AFTER UNITIZATION
MARCH, 1956 VS MAY, 1957
SMACKOVER POOL UNIT — MAGNOLIA FIELD, ARKANSAS
NOW OBTAINING GREATER OIL PRODUCTION
BEFORE 7403 BOPD
AFTER 12,664 BOPD
USING FEWER PRODUCING WELLS
BEFORE 97 WELLS
AFTER 40 WELLS
WITH A REDUCTION IN GAS-OIL RATIO
BEFORE 1,100 CU FT PER BBL
AFTER 802 CU FT PER BBL
AND DECREASED WATER PRODUCTION
BEFORE 10,954 BWPD
AFTER 478 BWPD
RESULTING IN LESS WATER INJECTION REQUIRED TO MAINTAIN PRESSURE
BEFORE 25,360 BWPD
AFTER 18,044 BWPD

FIG. 3. **Performance comparisons — before and after unitization** of Magnolia field showing average performance of Smackover reservoir in March 1956 just before unit formation vs unitized performance in May 1957.

completely stopping the injection program would eventually lead to significant losses in ultimate oil recovery. At this point, the field operators agreed that unitization might offer the only practical solution to the problem.

A Plan for Unitization

Early in 1952, field operators established geological, engineering and legal committees to study all aspects of the unitization problem.

The Magnolia Field Engineering Committee worked almost continuously on the problem from the spring of 1952 until September 1953. As a result of their extensive study, it was found that the program now being adopted under unitized operation would recover about 31,000,000 bbl more oil and condensate than the most favorable competitive plan.

Studies by the Engineering Committee disclosed two major problems which could be solved only through unitization if correlative rights of the various owners in the field were to be protected. These problems are (1) control of water movement into the field and (2) control of gas cap size.

The first of these problems, control of water movement, is shown in Fig. 2 by a series of four idealized cross-sections of the field.

As mentioned earlier, the easiest path for water influx has been up the flanks of the reservoir. The upper one-third of the Smackover porosity in the field appears to have a direct and permeable connection with the aquifer while the permeability development found in the lower two-thirds of the oil reservoir decreases down structure and becomes poor or non-existent away from the productive limits of the field. Because of this, it would have been virtually impossible to control and correct water movement into the reservoir under non-unitized operations. If this situation of non-uniform influx were allowed to continue, the water encroaching into the reservoir would eventually override and trap oil reserves in the lower zones of porosity.

Control of water movement. The program for correcting uneven water movement includes plans to discontinue injection into the four peripheral input wells so that water movement up to the flanks of the reservoir will be minimized. In place of the old injection wells, producing wells are being converted for injection below the present water-oil contacts in the lower zones of the field to move the water levels upward in these areas.

Obviously, such a program can be carried out only under unitized operation since injection wells located within the producing limits of the field would be out of the question on a non-unitized basis.

Control of gas cap. Control of gas cap size is the second major problem which was revealed by the studies of the Engineering Committee. Reservoir pressure has dropped considerably over the life of the field allowing the gas cap to expand. Since reservoir pressure is now being maintained by water injection, the gas cap is not expanding. Instead, the gas cap size is becoming smaller because the oil wells are producing some gas cap gas along with their oil production. The amount of cap gas production will increase as wells are plugged back due to rising water levels. If the gas cap were allowed to shrink to less than its original dimensions, then oil would be entering a zone which apparently had never been occupied by oil before. About one-third of the oil migrating into the

PRODUCTION – INJECTION HISTORY
SMACKOVER POOL
MAGNOLIA FIELD, ARKANSAS

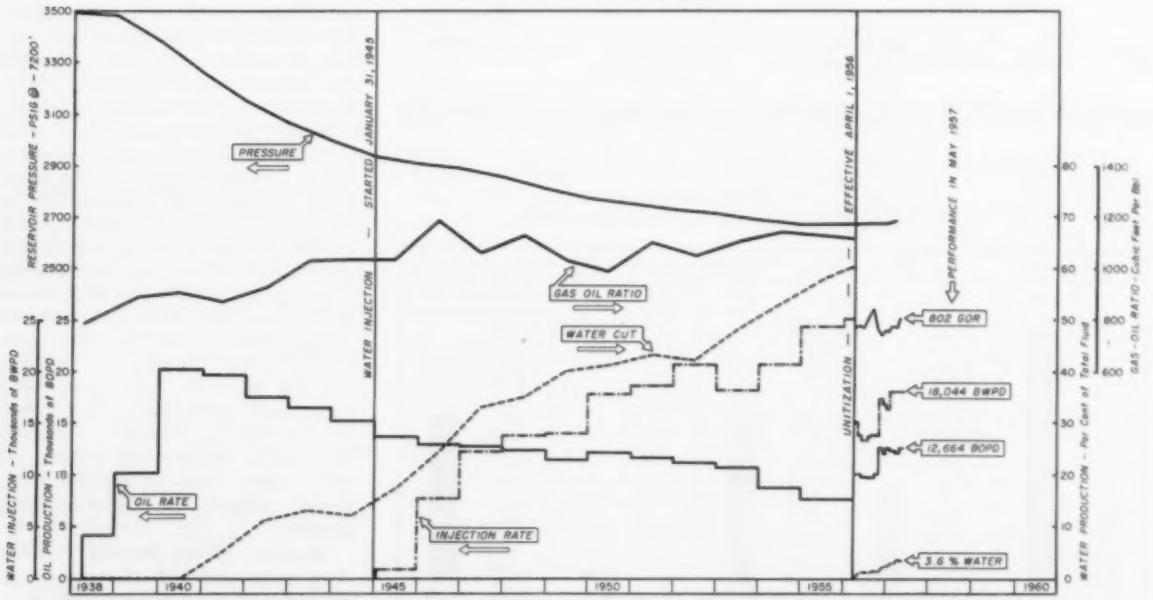

FIG. 4. Performance history of the Smackover reservoir in the Magnolia field showing improvement in producing characteristics since unitization and the effect of water injection on reservoir pressure.

space above the original gas-oil contact would remain trapped there as residual oil.

To prevent the loss of oil as a result of gas cap shrinkage, sufficient volumes of gas will be injected into the cap to maintain its size constant and replace the shrinkage caused by the production of cap gas from oil wells.

The problems of controlling water movement and gas cap size and the estimated stakes involved (31 million bbl of additional oil and condensate recovery) provided ample incentive for unitizing.

The equity basis for unitization was agreed upon by a substantial majority of the field's working interest ownership at an operators' meeting held in April 1954. The equity formula presented and adopted at that meeting is based on (1) remaining net acre-feet of pay as of January 1, 1953, adjusted for porosity variations and relative value of oil and gas pay, and (2) average daily oil production during the first six months of 1953.

Obtaining approval. The unitization laws of Arkansas specify that 75 percent of the working interest ownership and 75 percent of the royalty interest ownership must give their approval to a unitization project before it can become effective. Because of the close cooperation among the various operators in arriving at a basis for unitization, the required approval of the Magnolia Unit by the working interest owners was quickly obtained. By the time of the unitization hearing, more than 90 percent of the working interests had approved the Magnolia unitization agreement.

Acquiring the signatures of 75 percent of the working interest ownership on the unit operating agreement was a simple matter in comparison with the task of obtaining the necessary royalty owner approval. This field has more than 470 royalty owners living in 22 states. A more serious problem than this widespread distribution was the fact that several of the parties owning royalty in the field firmly refused to sign the unitization agreement. Even though these royalty owners realized the economic advantages of unitization, they were understandably reluctant to sign something which they felt would deprive them of their individuality of ownership. This attitude of independence demanded respect in view of the clearly defined benefits offered by unitization; nevertheless, it was the primary source of difficulty in getting the required 75 percent of royalty ownership approval.

The royalty owner sign-up took about nine months to complete. The techniques employed in this undertaking included extensive use of IBM equipment to prepare comparisons of rate of income and total income on an individual royalty owner basis. These tabulations proved to be very helpful in demonstrating the advantages of unitization. About 77 percent of the royalty interest ownership had executed the unit agreement at the time of the unitization hearing.

The final step in the four-year-long effort to unitize Magnolia field was presentation of the unitization proposal at a hearing before the Arkansas Oil and Gas Commission on March 15, 1956. The Commission approved the proposal and ordered unit operation to begin on April 1, 1956.

Performance Under Unitization

The Magnolia Unit is an excellent example of the performance improvement made possible by the flexibility of unitized operation. For comparison of field performance before and after unitization, the following table shows the increased producing efficiency which has been achieved.

	Before Unitization (March 1956)	After Unitization (May 1957)
Oil Producing Rate (BOPD):	7,403	12,664
Number of Producing Wells Being Used:	97	40
Gas-Oil Ratio (Scf/STBO):	1,100	802
Water Production (BWPD):	10,954	478
Water Percentage:	60%	4%
Water Injection Rate (BWPD):	25,360	18,044
Reservoir Pressure:	2,679	2,684
(psig at datum of 7200 feet subsea)	(April 1956)	(April 1957)

The above comparison demonstrates that:

1. The less efficient production of excess gas and water which was occurring before unitization has almost been eliminated under unitized operation.
2. Even though the producing rate of the field was increased by about 70 percent, oil is now being produced more efficiently than before while using a much smaller number of wells.
3. As a result of more efficient production, the amount of water injection required to maintain reservoir pressure has been substantially decreased.

Significant savings in operating costs have been realized since unitization. The Unit Operator, Atlantic, has been producing the 12,500 bbl daily oil rate

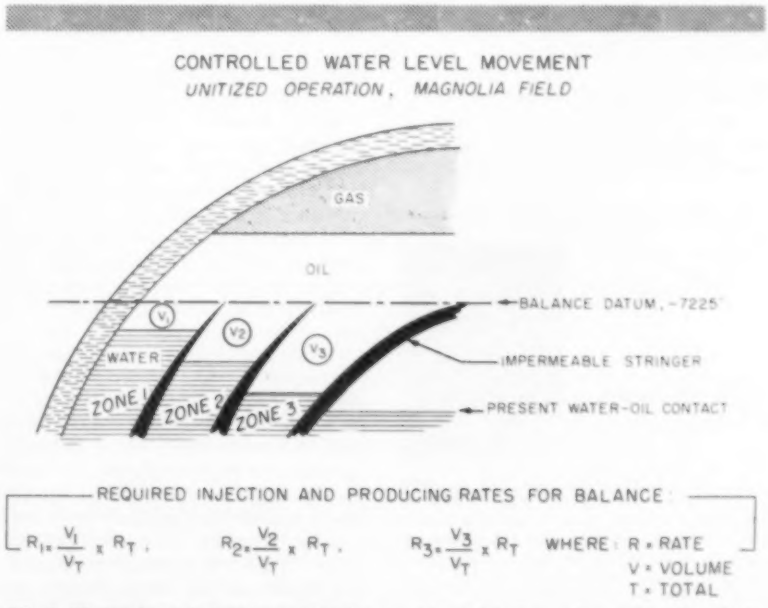

FIG. 5. **Water level balancing operation** consists of bringing various water-oil contacts to a common datum at the same time. Schematic cross-section shows conditions in west end of reservoir where V_1, V_2 and V_3 are the remaining oil volumes between current water levels and balance datum in Zones 1, 2 and 3.

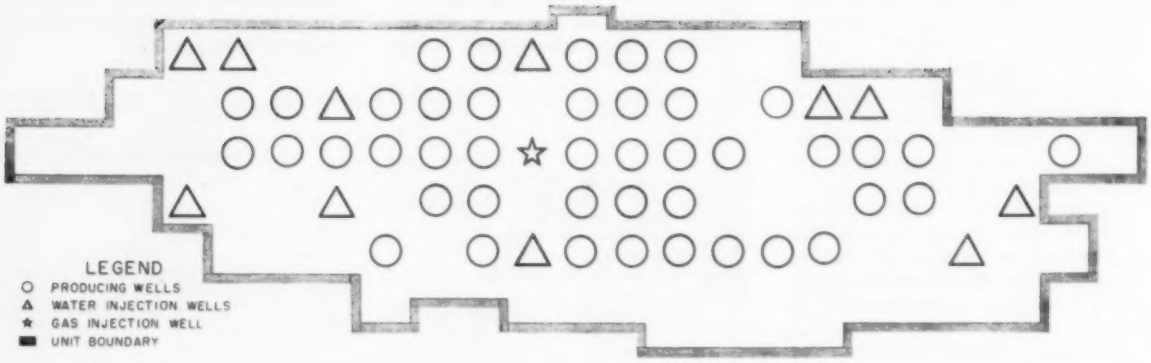

FIG. 6. **Unitized plan of operation** during water level balancing phase calls for use of 11 water injection wells, shown as triangles. The gas injection well required to maintain gas cap size is represented by a star. Black circles indicate wells scheduled for use as oil producers.

with the same field production staff it employed to produce its 2000 bbl per day share of field production prior to unitization. To illustrate the savings involved, Atlantic's average direct operating costs in the field on a cost per barrel basis have been reduced to, roughly, one-third of what they were just before unitization.

A graphical presentation of comparative field performance is shown in Fig. 3, and the production-injection history of the Smackover reservoir is plotted in Fig. 4.

Cumulative oil production from the Smackover pool of Magnolia field was about 82,900,000 bbl up to the date of unitization. Total oil production under unitized operation, from April 1, 1956, to June 1, 1957, has been about 4,800,000 bbl.

Unitized Plan of Operations

In developing the broad concepts of the Engineering Committee into the specific details of a plan of unitized operations, the Unit Operator's most difficult job was formulating a system of producing and injection wells to correct uneven water movement and minimize by-passing of oil.

Analysis of the reservoir in three dimensions showed that the lower half of the remaining oil zone could be divided into thirteen individual zones, each with its own water level and reservoir characteristics. Further study indicated that treating these zones separately with individual zone systems of injection and producing wells would make it possible to bring all the water levels in the field to a common datum at the same future time.

The water level balancing operation is illustrated in Fig. 5 which is an idealized cross-section representing conditions in the west end of the reservoir. By constructing isopachs of the thirteen zones discussed above, it was possible to calculate the unflooded oil volumes remaining in each zone between the present water-oil contacts and a balance datum of 7225 ft subsea. In order to flood out all of the zones to a common water level at the same time, the desired rates of injection and withdrawal for each zone were established as being directly proportional to the volume of that zone.

Having determined the withdrawal and injection rates required for the various zones, the problem then was resolved into making flood studies on an individual zone basis. The wells which appeared to provide the most satisfactory pattern and the required injectivity or productivity characteristics were chosen from the existing wells available for use. Fig. 6 shows the producing well-injection well arrangement scheduled for the water level balancing phase of unitized operations.

Well Workover Program

An extensive well workover program has been undertaken to establish the new system of injection wells, producing wells and brine make-up water supply wells required by the plan of operations for the Unit. The workover program calls for the conversion of eleven existing wells to water injection wells in the Smackover. Most of these jobs necessitate deepening the wells for completion in lower zones of the reservoir. Nine of the eleven injection well workovers had been completed as of August 1, 1957.

To fit with the new injection well system, a program of corrective work has been scheduled for producing wells. This producing well workover program consists of fifteen deepening or recompletion jobs. As of August 1, 1957, nine of the producing well workovers had been completed.

The make-up water, which has been injected into the Smackover formation since the pressure maintenance system was instituted in 1945, has come from a fresh water zone of the Sparta formation located at a depth of about 400 ft. In keeping with the plan of unitized operation, use of this fresh water will be discontinued as soon as a satisfactory source of salt water can be developed.

In exploring for an adequate make-up water source, four formations have been partially evaluated to date. These formations are: The Wilcox Sand at a depth of 1100 ft, the Nacatoch Sand at a depth of 1800 ft, the Tokio Sand at 2900 ft and the James Lime at 3900 ft. The Tokio formation appears to be the most satisfactory supply source tested thus far. Presently, laboratory and field testing of Tokio water quality is underway.

The Unit operators are spending about $1 million initially in putting the unitized plan into operation. Later on, further investments will be required to assure the 31,000,000 bbl of increased oil and condensate recovery predicted for unitized operations. * *

The Author

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How to . . .

Evaluate Gas Well Damage

By Pressure Build-Up Tests

Routine well problems may now be analyzed and solved as a result of tests, using recent studies of unsteady flow of compressible fluids in porous media

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Dallas, Texas

IF the permeability of a producing formation is significantly reduced in the immediate vicinity of a well bore, the productivity of the well is seriously damaged. The pressure build-up test has, in the past few years, gained increasing acceptance as a tool to detect such local permeability impairment, and to select those wells in which remedial work to improve productivity is indicated. Comparatively recent investigations (see references) of the unsteady flow of compressible fluids in porous media have made it possible to use build-up tests in the analysis of routine well problems.

The general expression describing the pressure behavior of a compressible fluid in a porous medium is a nonlinear partial differential equation. Solutions of this equation have been developed for boundary conditions which are encountered in the majority of producing well systems and for rate conditions which can be imposed in most cases.

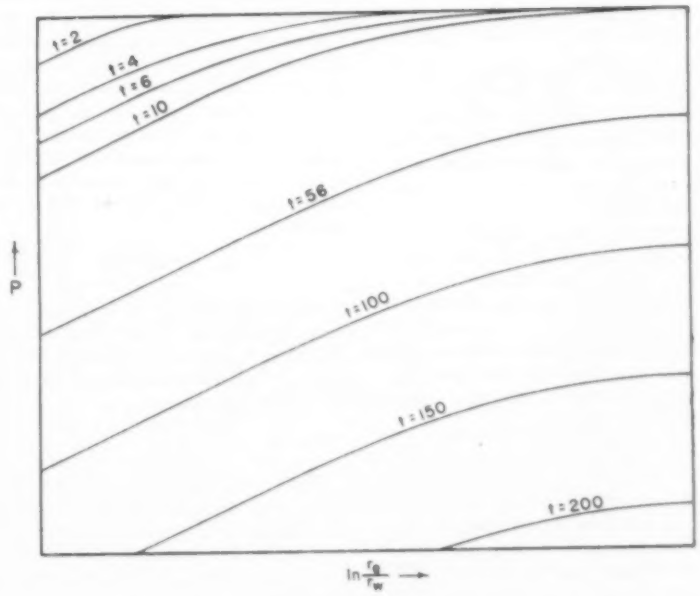

FIG. 1. **Generalized pressure distribution** during depletion of radial system with no flow across the exterior boundary.

Pressure Distribution

The sequence in which pressure distribution within a cylindrical drainage system varies with time and radius is presented in generalized fashion in Fig. 1. From this porous cylindrical system, a compressible fluid is produced at constant rate from a well bore centered at the axis.

Here it is seen that removal of fluid at the interior boundary of the system results in the reduction of pressure at successively greater distances from this boundary, until the pressure at the exterior boundary is affected. In well systems encountered in practice the conditions imposed at the exterior boundary may range from no flow across this boundary, to those of constant pressure at the exterior boundary. In the latter case, as much fluid is entering the system across the exterior boundary as is removed at the interior boundary.

Fig. 1 describes a system with no flow across the exterior boundary. During the time that the cylinder affected by production of fluid is expanding, or the time before the transient reaches the exterior boundary, the pressure distribution in the system is undistinguishable from that of an infinite system. After the transient reaches the exterior boundary, the pressure distribution begins to depart from that characteristic of the expanding radius of influence. With increasing time, pressures approach the steady-state distribution characteristic of the appropriate boundary conditions. In this case, where there is no flow across the exterior boundary, the steady-state distribution is characterized by equal pressure changes at all radii during a given interval of time. Using the results of previous investigators,[1] it is possible to approximate the time at which the transient established by production will reach the exterior boundary, and also the time required for the system to approach steady-state pressure distribution.

Build-Up Test Interpretation

To evaluate the damage caused by local permeability impairment, a comparison of the productivity of the existing well system to the productivity of the same system without local permeability reduction is desired. In the case of gas wells it is convenient to use the ratio of the pressure drop calculated for the undamaged system to the total pressure drop observed.

Proper evaluation of the boundary conditions in a well system is important to the interpretation of build-up test data. The conditions prevailing at the time the well is shut in should be estimated to avoid the necessity of repeating the build-up test. First it should be decided whether the pressure transient, originating when the well was originally opened to production, has reached the limits of the drainage area. The time required for this may be approximately estimated using the following Equation 1:

$$t = \frac{265.5\, f\mu c r_e^2}{k} \quad . \quad . \quad . \quad (1)$$

If the well has been produced for a time equal to or less than that estimated with Equation 1, its behavior will be indistinguishable from that of a well draining an infinite system, and an analysis appropriate to this system should be used.

If the well has been produced for a time longer than that obtained from Equation 1, the well should be produced at a constant rate for a time sufficient for the system to approach a stabilized or steady-state pressure distribution. The time required for this may be approximately estimated using the following relation:

$$t_s = \frac{1472\, f\mu c r_e^2}{k} \quad . \quad . \quad . \quad . \quad (2)$$

With the well stabilized at time of shut in, it will also be necessary to decide if the well is in a volumetric reservoir, in which case it may be concluded that there is no flow across the exterior boundary. If the well is in a water drive reservoir, some part of the fluid produced at the well is replaced by fluid crossing the exterior boundary. This ratio should be estimated.

At this point it has been decided whether boundary conditions appropriate to an infinite system, a stabilized system with no flow across the exterior boundary, or a stabilized system with constant pressure at the exterior boundary should be assumed.

In making the build-up test a bottom-hole pressure bomb is run in with the well flowing, the well is shut in, and a continuous record obtained of pressure and time for the duration of the shut in period. If the well is shut in at the surface, the effect of afterflow into the casing will affect the early part of the build-up curve. After the storage of gas into the casing ceases to have a significant effect, it has been shown[1, 2, 3] that the build-up curve, P versus 1 n $(\sigma/t + \sigma)$ for the infinite system, P versus $1n\sigma$ for stabilized systems, has a slope, m, which is related to the capacity of the formation in the undamaged portion of the system as follows:

$$m = 162.5\, \frac{q\mu}{kh} \quad . \quad . \quad (3)$$

The flow rate, q, in this equation must be measured at the pressure prevailing at the interior boundary of the system. This may be easily done using the following relation:

$$q = Qv = \frac{Q(5.018\, Z_w T)}{P_w} \quad . \quad . \quad (4)$$

The value of m may be obtained from build-up test data by measuring the change in pressure observed over one cycle of a semi-log plot of pressure versus time and substituting in Equation 5.

$$m = \frac{P_1 - P_2}{2.3026} \quad . \quad . \quad . \quad . \quad (5)$$

When the permeability in the immediate vicinity of a well bore is significantly different from that in the interwell area, the pressure drop through this cylinder of low permeability may be considered directly proportional to the flow rate with negligible error, provided that the radius affected is small with respect to the radius of the system. At this point it is helpful to make use of the skin factor, S, as suggested by A. F. Van Everdingen.[3] Defining S as the pressure drop through the affected cylinder per unit rate of flow (162.5 μ/kh), we may obtain the value of this factor from the following Equation 6 or 7. $P\sigma$ and σ in these equations are any corresponding time and pressure from the linear portion of the build-up curve.

$$\text{Infinite System } 2S = \frac{P\sigma - P_w}{m} - \left[1n\ 0.0002636\, k \left[\frac{\frac{1}{\frac{1}{\sigma} + \frac{1}{t}}}{f\mu c r_w^2}\right] + 0.80907\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$\text{Steady State } 2S = \frac{P\sigma - P_w}{m} - \left[1n\ 0.0002636\, \frac{k\sigma}{f\mu c r_w^2} + 0.80907\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

However, if it is large with respect to σ Equation 7 may be used in all cases.

To determine the pressure drop ratio, it is necessary to determine the pressure at the exterior boundary of the system. For the infinite system it is necessary only to extend the linear portion of the build-up curve to the value 1 n $(\sigma/t + \sigma) = 1$, the value of P corresponding is equal to the desired pressure. For the other boundary conditions Equation 8 or 9 below may be used.

Steady State,
No flow across
exterior boundary

$$P_e = P_w + 2mS + m\left[2\ 1n\ \frac{r_e}{r_w} + 1\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Steady State,
Constant pressure
at exterior boundary

$$P_e = P_w + 2mS + m\left[2\ 1n\ \frac{r_e}{r_w}\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Finally, for all boundary conditions

Symbols

- c Compressibility, vol/vol/psi
- C_p Pressure drop ratio, total pressure drop in undamaged system/pressure drop observed
- σ Build-up time measured from shut in, hours
- f Net porosity occupied by hydrocarbons, fraction
- h Net productive formation open to production, feet
- k Permeability, md
- m Slope of back-pressure curve, $dP/d\ 1n\sigma$
- P Pressure, psia
- P_w Flowing bottom-hole pressure, psia
- $P\sigma$ Bottom-hole pressure at time σ, psia
- P_e Pressure at exterior boundary of system, psia
- Q Producing rate prior to shut in, Mscf/d
- q Producing rate at reservoir conditions, reservoir barrels per day, evaluated at $P = P_w$
- ρ Density
- r_w Radius to interior boundary of system, feet
- r_e Radius to exterior boundary of system, feet
- S Skin factor, pressure drop through damaged zone for unit rate of flow, $q = 162.5\mu/kh$
- T Formation temperature, °R
- t Production time, measured from initial production, hours
- μ Viscosity, cp
- v Gas reservoir volume factor, reservoir bbl/Mscf
- z Deviation factor

considered above, we may determine the pressure drop ratio from

$$C_p = \frac{P_e - P_w - 2mS}{P_e - P_w} \quad (10)$$

Consistency with the development of the foregoing relations requires that q, the flow rate at reservoir conditions, be evaluated at the pressure which would prevail at the interior boundary in the absence of local permeability impairment. This pressure is equal to $P_w + 2mS$. If the values of P_w and $P_w + 2mS$ differ by more than a few percent, significant error is introduced by measuring the flow rate, q, at P_w. One additional calculation, using the value of $P_w + 2mS$ found initially, is usually enough to bring the pressure used into satisfactorily close agreement with the final pressure determined. In like manner, the compressibility and viscosity should be evaluated at the average pressure of the undamaged system.

Prior to accepting the result of these calculations, the original preliminary estimates of stabilization time (or time during which behavior is indistinguishable from that of an infinite system) which were made using Equation 1 or 2 should be rechecked using the value for permeability determined with Equation 3.

Limitations

In the development of the foregoing relations a number of assumptions were made which limit the application of the comparatively simple interpretation presented. It is the author's opinion that the majority of well systems can be handled by the methods which have been discussed, yet it should be realized that wells are encountered for which these methods provide no satisfactory solution. These cases can for the most part be recognized, as will be shown.

It is assumed that compressibility is small and constant; explicitly, it is assumed that

$$\rho = \rho_0 [1 - c (P_o - P)]$$

The above relation implies that the compressibility throughout the system is equal to c_o, or that the compressibility is the same at the interior and exterior boundaries of the system. If the average of compressibilities calculated at the interior and exterior boundary of the system are used, it is believed that reliable results can be obtained, provided that these pressures do not differ by more than 20 percent.

It is assumed that the system is essentially radial; this is, of course, the case for infinite behavior, but for bounded reservoirs significant departures from radial flow are encountered in practice. Matthews, Brons, and Hazebroek[4] have investigated the effect of such departures. The performance of a well located near the center of a drainage area which is a regular polygon of more than three sides does not differ significantly from strictly radial performance. If the well is located in more complicated fashion with respect to its drainage boundaries, the techniques suggested in the above referenced paper can be applied in most cases.

It is assumed that the system considered is homogeneous. It is the author's opinion, which has some support, that fairly large departures from uniform permeability and porosity do not have a significant effect on the total build-up performance. This is the case, however, only if there are not intervening impermeable beds. If beds of significantly different permeability are separated by impermeable strata, so that in effect the well is open to two or more separate zones, the methods of analysis suggested are not applicable. Nor is this type of analysis recommended for systems having long fractures.

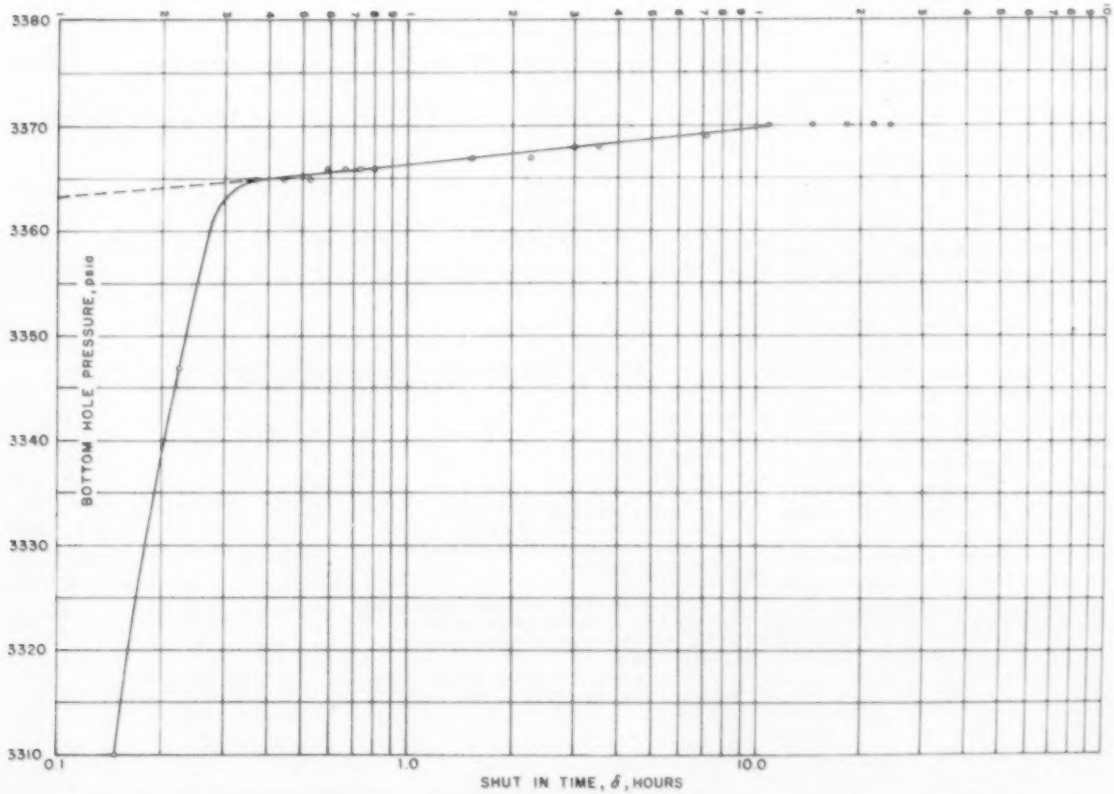

FIG. 2. **Pressure build-up test** of Well "A." This well is an interior well in a multiwell reservoir. Test was made because well productivity was significantly lower than that of other wells in the same field.

Field Applications

The reciprocal of the pressure drop ratio determined by build-up test interpretation is, at least qualitatively, an indication of the amount of improvement in productivity which successful remedial work may accomplish. Once it is concluded that local wellbore damage is present, the problem of profitably eliminating it remains.

No remedial scheme has been found to be uniformly effective in eliminating all cases of local permeability impairment. Various possible causes of local damage have been suggested, such as infiltration of mud fines into the formation, swelling of native bentonitic clays after exposure to mud filtrate, and water blocking.

In practice it is seldom known which of these causes is responsible for the reduced productivity of a specific well. Remedial measures are directed either at restoring the original permeability of the formation or at providing channels of high permeability through the damaged zone. Restoration of all or part of the permeability in the damaged zone has been accomplished by the injection of acid, surfactants, or combinations of both.

Fracture treatments have been successful in creating flow channels between the well bore and the undamaged portion of the formation. A complete sample calculation for a well with a very low-pressure drop ratio is presented for the assistance of those who may wish to apply the method previously outlined. This well was subsequently acidized; the acidizing procedure and its results are discussed.

Well "A" is an interior well in a multiwell reservoir. The build-up test was made because the productivity of the well was significantly lower than that of other wells in the field. Review of the electrical logs, core data and producing interval failed to reveal reasons why this should be the case. At the time of this consideration, additional deliverability was needed from the field to meet certain contractual obligations. A preliminary estimate of the permeability of the sand from core data indicated an average permeability of about 350 md. From field spacing and production rates, a drainage radius of approximately 1500 ft was estimated. The build-up test data obtained are plotted in Fig. 2; pertinent well data are tabulated below.

Q = Producing rate prior to test = 4,429 Mcf/d

Full stream gas gravity = 0.691 (Air = 1)

T = Bottom hole temperature = 710° R

P_w = Flowing bottom-hole pressure prior to shut-in = 3159 psia

Highest pressure observed during test = 3370 psia

Z_w = Deviation factor at P_w = 0.918

r_w = Well bore radius = 3.5 in. = 0.292 ft

h = Net productive formation thickness = 40 ft

The flowing rate must be measured at conditions prevailing at the interior boundary of the system. In this case

$$v = \text{Gas reservoir volume factor} = \frac{5.018\, Z_w T}{P_w}$$

reservoir bbl/Mscf.

$$v = \frac{(5.018)\,(0.918)\,(710)}{3159} =$$

1.0353 reservoir bbl/Mscf

$$q = Qv = (4429)\,(1.0353) = \underline{4585}$$

reservoir bbl/d.

Strictly, the flow rate at reservoir conditions should be measured at the pressure which would prevail at the interior boundary if the damaged zone were eliminated. This flow rate can be recalculated if the results of subsequent calculation reveal that this pressure is significantly different from P_w.

A preliminary estimate of the time required to stabilize is made. Properties related to Equation 1 and 2 are system properties and should be measured at the average system pressure, in this case 3159 + 3370/2 = 3265 psia. For estimates of compressibility the method suggested by Trube[6] is recommended.

c = compressibility = 2.67×10^{-4} vol/vol/psi,

μ = viscosity = 0.0210 cp,

f = net porosity = 0.156.

Since the well is in an interior location, only the time required to stabilize need be calculated.

$$t = 1472\,\frac{f\mu c r_e^2}{k} =$$

$$\frac{(1472)\,(0.156)\,(0.0210)\,(2.67 \times 10^{-4})\,(1500)^2}{350}$$

$$t = \underline{8.4 \text{ hours}}$$

Prior to the test on this well, it was produced at a constant rate for two weeks. We now surmise that the well is in a stabilized condition prior to the build-up test, based on a preliminary conjecture as to the permeability of the interval open to production. Further field information indicates that the well is completed in a volumetric reservoir, from which we conclude that no flow occurs across the exterior boundary. From the build-up curve (Fig. 2) we obtain

$$m = \frac{P_1 - P_2}{2.3026} = \frac{(0.5)\,(6.5)}{2.3026} = \underline{1.41}$$

$$k = 162.5\,\frac{q\mu}{hm} =$$

$$\frac{(162.5)\,(4585)\,(0.0210)}{(40)\,(1.41)} = \underline{277 \text{ md.}}$$

After selecting corresponding values of σ (shut-in time), and P_σ (bottom-hole pressure), the skin factor, S, is calculated from Equation 7.

$$2S = \frac{P_\sigma - P_w}{m} -$$

$$\ln 0.0002636\,\frac{k\sigma}{f\mu c r_w^2} - 0.809$$

From Fig. 2 we arbitrarily select σ = 1.5 hr and P_σ = 3367 psia

$$2S = \frac{3367 - 3159}{1.41} - \ln 0.0002636$$

$$\left[\frac{(277)\,(1.5)}{(0.156)\,(0.0210)\,(2.67 \times 10^{-4})\,(0.292)^2}\right]$$

$$- 0.809$$

TABLE 1. Pertinent Data and Conclusions, Build-Up Test Analyses, Well "B" and Well "C".

Basic Data	Well "B"	Well "C"
f, net porosity	0.120	0.1275
h, net producing sand, ft	61	15
r_w, wellbore radius, ft	0.276	0.25
r_e, exterior radius of system, ft	1,550	1,200
Q, producing rate prior to shut-in, Mscf/d	4,386	4,774
Specific gravity, full stream, (Air = 1)	0.675	0.630
P_w, bottom-hole pressure prior to shut-in, psia	3,592	3,527
Preliminary Estimates		
k, permeability, md	25	300
P_w+2mS, flowing pressure undamaged system, psia	4,207	—
$(P_w+2mS+P_e)/2$, average system pressure, psia	4,297	—
t_s, time required to approach stabilization, days	3.0	0.2
Calculated Values		
q, flow rate at reservoir conditions, bbl/day	3,671	4,476
m, slope of build-up curve	13.03	4.99
S, skin factor	20.8	−0.35
k, md	17.6	209
P_w+2mS, psia	4,134	3,521
P_e, psia	4,372	3,610
$(P_w+2mS+P_e)/2$, psia	4,253	3,566
t_s, days	4.2	0.3
C_p	0.305	1.08

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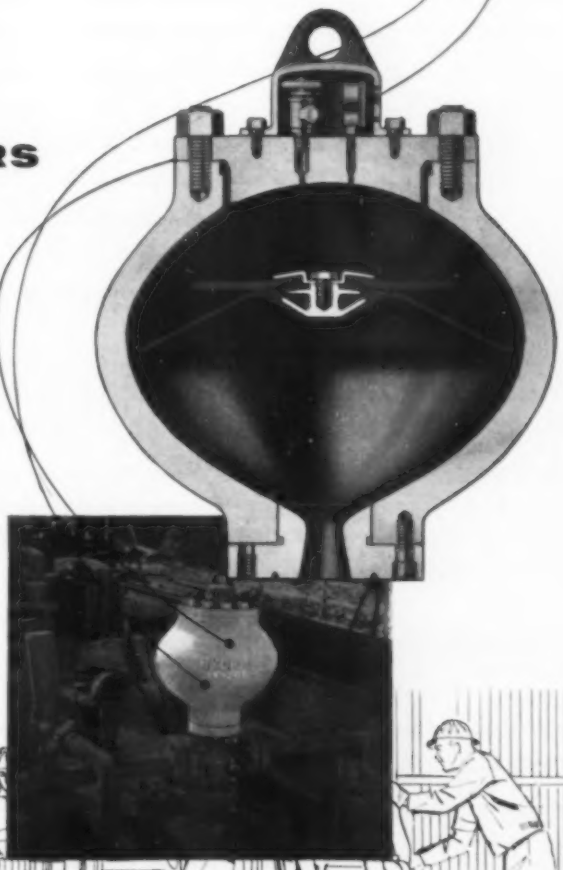

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$$2S = 147.5 - 14.2 - 0.8 = \underline{\underline{133}}$$

The pressure at the exterior boundary may now be computed using Equation 8.

$$P_e = P_w + 2mS + m\left[2 \ln \frac{r_e}{r_w} + 1\right]$$

$$P_e = 3159 + (1.41)(133) + 1.41\left[2 \ln \frac{1500}{0.292} + 1\right]$$

$$P_e = 3159 + 187.5 + 24.1 = \underline{\underline{3371 \text{ psia}}}$$

Finally the completion ratio is calculated

$$C_p = \frac{P_e - P_w - 2mS}{P_e - P_w} = \frac{3371 - 3159 - 188}{3371 - 3159} = \frac{24}{212} = \underline{\underline{0.113}}$$

The final check on the assumptions made as to the stabilization time may be made by inspection. It is evident that the stabilization time of two weeks prior to the test is still more than adequate in the light of the permeability determined from the build-up curve. The pressure at which q, the flow rate at reservoir conditions, should be evaluated is 3347 psia rather than 3159 psia; the error introduced by this substitution is not significant in this case, however.

Because of the very low-pressure drop ratio of this well, remedial work was performed. The well was acidized with 2000 gal of mud acid to which a surfactant was added. It was suspected that, if by-passing part of the damaged zone surrounding the well bore were to be avoided, formation breakdown was undesirable. For this reason, bottom-hole pressures during the injection of the acid were kept below the estimated formation breakdown pressure. The absolute open flow potential of the well prior to acidizing was 18,200 Mcf per day, after acidizing 78,000 Mcf per day.

Two additional examples of build-up test analysis are presented in Table 1; build-up curves obtained are included as Fig. 3 and 4.

Well "B" is completed in a tight, high-pressure gas sand and has a relatively high degree of local permeability impairment. In this case, it was of some assistance to make a preliminary estimate of flowing pressure of the undamaged system.

Well "C" has an open hole completion in a sand of relatively high permeability. The well has a small negative skin factor, indicating a permeability in the immediate vicinity of the well bore higher than that in the interwell area. In this case, the increased permeability indicated may be a result of an actual wellbore diameter larger than that assumed. As a result of this test, the well has been conclusively eliminated as a prospect for the type of remedial work considered here.

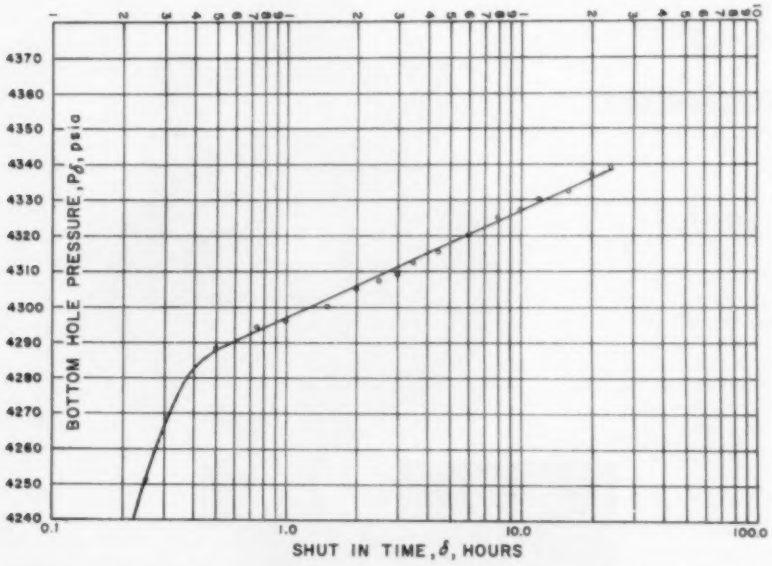

FIG. 3. **Pressure build-up curve** of Well "B." It was completed in a tight, high-pressure gas sand and has a relatively high degree of local permeability impairment.

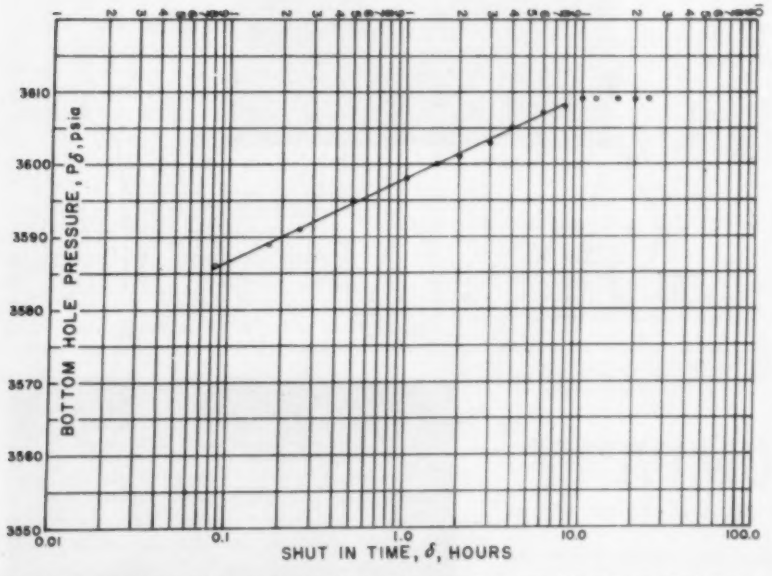

FIG. 4. **Pressure build-up curve** of Well "C." As a result of test, this well was eliminated as a prospect for remedial work being considered.

Acknowledgment

The author wishes to express his appreciation to the Delhi-Taylor Oil Corporation for permission to prepare this paper originally presented on Texas A & I College's Annual Short Course in Gas Technology. The course was sponsored by the Southern Gas Association.

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★ ★ ★

Mobile field radiation-instruments laboratory used in the radiotracer experiments. This partial view of the interior of the truck shows F. E. Armstrong, electronics engineer, with recorders, counting-rate meters and oscilloscope.

Physical chemist R. J. Heemstra makes adjustments on gasoline-powered electric-generating plant of the field radiation-instruments lab while making tracer experiments.

Waterfloods Benefit by . . .

Radioactive Tracer Techniques

- Non-uniform conditions in and between wells detected and evaluated by radioactive tracers
- Sweep efficiencies of waterflooding improved and production increased through better understanding of fluid flow in reservoir

J. W. Watkins*
E. S. Mardock**
F. E. Armstrong*
and R. J. Heemstra*

RADIOACTIVE isotopes are now playing an important role in giving reservoir engineers a vivid picture of subsurface fluid flow from water-input wells, oil-production wells, and between wells within a secondary-recovery project. Unconformities in flow characteristics and in formations themselves may now be detected and evaluated by the use of radiotracers. End result of the use of these by-products of an atomic age — radiotracers — is that sweep efficiencies of flood waters in recovery projects are improved and oil production is increased.

Radioactive tracers are the newest aid to long-time efforts to track the flow of water through subsurface permeable soils and rock formations. These studies in ground-water hydrology date back many years before petroleum was produced commercially and have been made in the oil industry almost from the time of its inception.

In any water-tracer study, failure of the tracer to appear at preselected detection points may be due to many causes and is difficult to interpret. Two principal causes are adsorption of the tracer on solid surfaces and ion exchange, which may cause insoluble compounds to form and precipitate. Laboratory experiments to select tracers with desirable adsorption and solubility characteristics have been described elsewhere. The use of two radioactive anions, iodide 131[4] and chloroiridate 192[6] has been studied. Lacy and de Laguna[5] have reported experiments that demonstrate the utility of chelated metallic cations.

The utility of water tracers has been extended during the past several years by the general availability of radioactive isotopes. The use of gamma-emitting radioisotopes permits making measurements in the bores of oil wells to determine water-production profiles as described by Watkins and Mardock,[7] and water-input profiles by various methods as described by Edwards and Holter,[2] Flagg et al,[3] and Bird and Dempsey.[1] Thus, detection and evaluation of heterogeneities that adversely affect petroleum production have been made possible by radiotracer techniques.

EXPERIMENTAL TRACER METHODS

Field techniques employed have been described in some detail in earlier publications.[6, 7] Briefly, a field test site is selected by reviewing all data available pertaining to numerous water-input and oil-production wells to determine whether non-uniform conditions are indicated. Such data may include core analyses, water-injection and fluid-production records, and special well-head tests.

On the basis of the preliminary evaluation, a group of wells is selected for a tracer test. Inasmuch as the "5-spot" pattern of drilling usually is employed on waterfloods where the area and other characteristics of the pool permit, the group of wells selected usually is an inverted 5-spot, which consists of one input well in the center of a square and four production wells in the corners of the square. Distances between like wells may run from 300 to

*Bureau of Mines, U. S. Department of the Interior, Bartlesville, Oklahoma.
**Well Surveys, Inc., Tulsa, Oklahoma.
Information in this paper, originally titled "Utility of Radioactive Tracers in and Between Wells of Waterflooded Petroleum Reservoirs," was presented as part of a Symposium on Nuclear Technology in the Petroleum and Chemical Industries at the American Chemical Society meeting in Miami, Florida, April 8, 1957.

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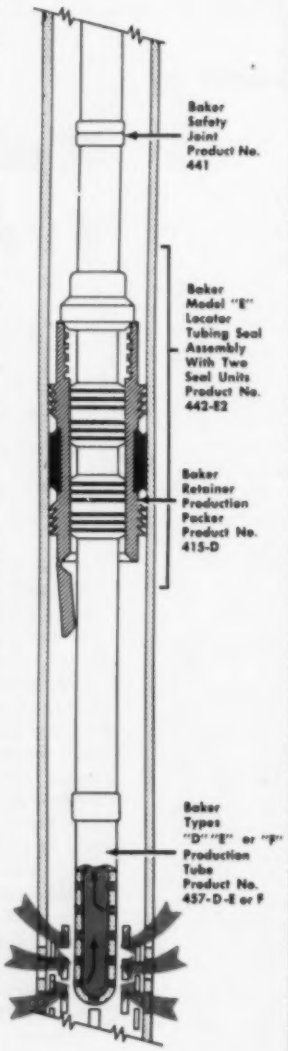
Baker Safety Joint Product No. 441
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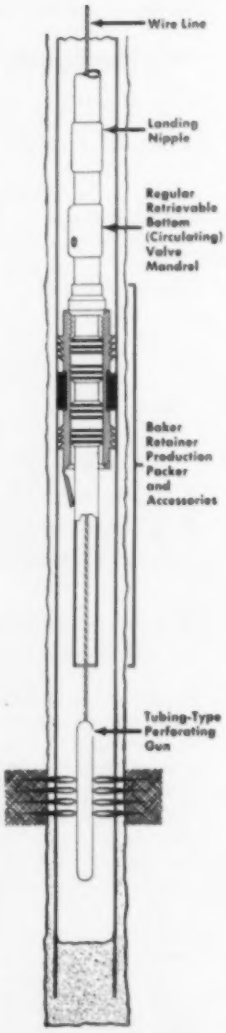
Illustrates Packer set in casing with Locator Tubing Seal Assembly and Production Tube installed for single-zone production.



Illustrates typical Permanent-Type Well Completion Hook-Up showing perforating operation through and below the Packer.

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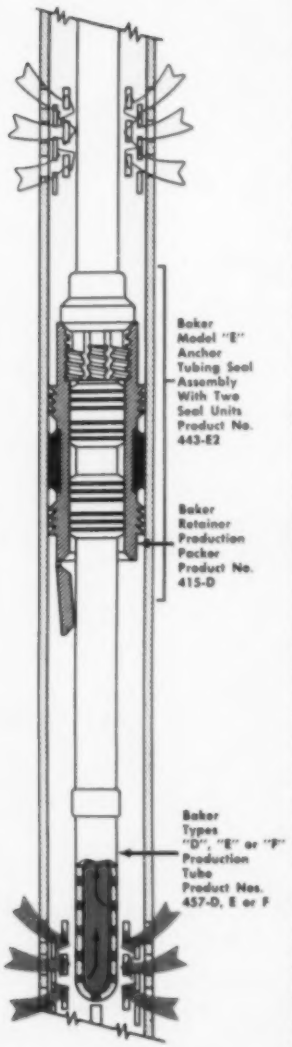
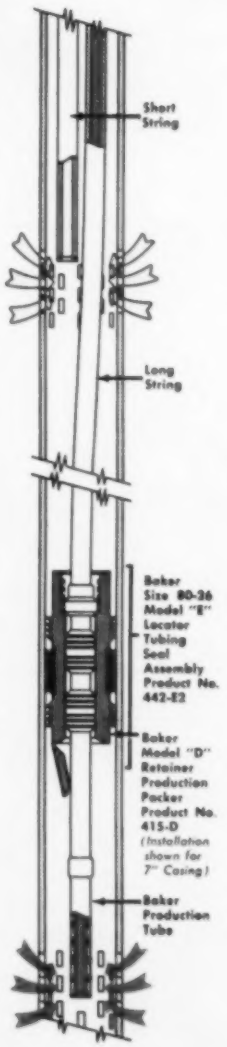

Baker Model "E" Anchor Tubing Seal Assembly With Two Seal Units Product No. 443-E2
Baker Retainer Production Packer Product No. 415-D
Baker Types "D", "E" or "F" Production Tube Product Nos. 457-D, E or F

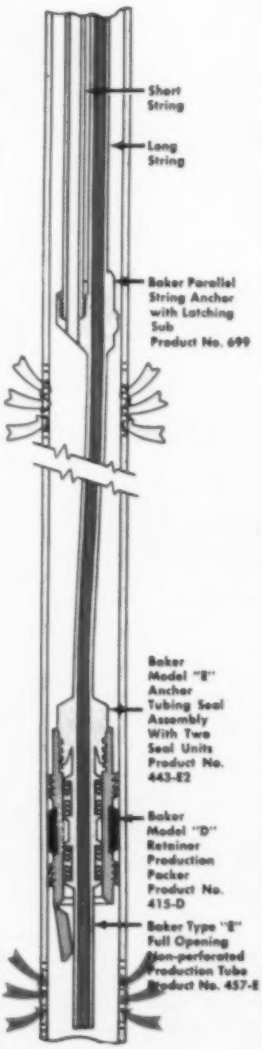
Illustrates Packer set in casing, with anchored production string for dual-zone production. Tubing can be released from Packer by rotating to right.

DUAL ZONE
Parallel String Short String Hanging Free


Short String
Long String
Baker Size 80-36 Model "E" Locator Tubing Seal Assembly Product No. 442-E2
Baker Model "D" Retainer Production Packer Product No. 415-D
(Installation shown for 7" Casing)
Baker Production Tube

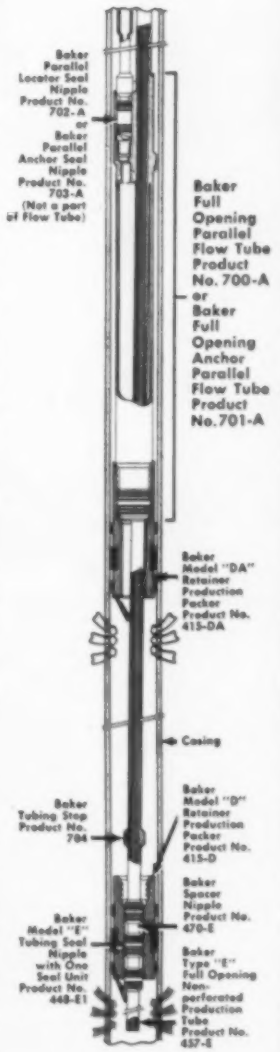
Permits removal of either string independently of the other regardless of sequence. Full-Opening (Tubing I.D.) Long String to lower zone.

DUAL ZONE
Parallel String Short String Anchored

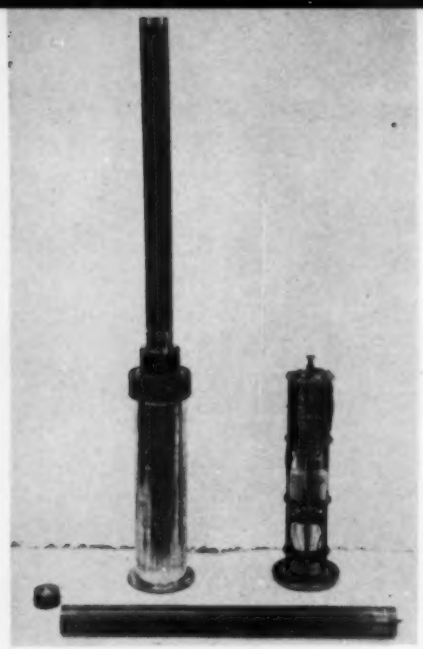

Short String
Long String
Baker Parallel String Anchor with Latching Sub Product No. 699
Baker Model "E" Anchor Tubing Seal Assembly With Two Seal Units Product No. 443-E2
Baker Model "D" Retainer Production Packer Product No. 415-D
Baker Type "E" Full Opening Non-perforated Production Tube Product No. 457-E

Permits removal of either string independently of the other, however long string must be run first. Short string pulled first. Full-Opening (Tubing I.D.) Long String.

DUAL ZONE
Parallel String Two-Packer Hook-up


Baker Parallel Locator Seal Nipple Product No. 702-A or Baker Parallel Anchor Seal Nipple Product No. 703-A (Not a part of Flow Tube)
Baker Full Opening Parallel Flow Tube Product No. 700-A or Baker Full Opening Anchor Parallel Flow Tube Product No. 701-A
Baker Model "DA" Retainer Production Packer Product No. 415-DA
Casing
Baker Tubing Stop Product No. 704
Baker Model "D" Retainer Production Packer Product No. 415-D
Baker Spacer Nipple Product No. 470-E
Baker Model "E" Tubing Seal Nipple with One Seal Unit Product No. 448-E1
Baker Type "E" Full Opening Non-perforated Production Tube Product No. 457-E

Illustrates Two-Packer parallel string installation with each zone confined to its individual tubing string with full-opening to lower zone for use of all permanent-type completion tools.



Wellhead radiation-detection unit, left, assembled; at right, disassembled.

Inserting the radiation-detection unit into the wellhead is done by author F. E. Armstrong.

Making radioactive tracer survey using portable mast over well. Hoist truck, left, and instrument truck in background.

more than 600 ft, depending upon the depth of the productive formation and the resultant economics of the project.

Background logs are made in all wells to determine the natural gamma radioactivity of the exposed formation. A water-input profile is made by a method[3] using a sized suspension of a radioactive tracer. A water-soluble, gamma-emitting tracer then is injected while normal injection rates and pressures are maintained. Usually this is done in two steps. A primary "slug" of tracer is injected to determine the time required for the tracer to travel down the tubing of the input well, through the formation, and up the tubing of the various production wells at which the tracer is expected to appear.

First slug. From the time of injection of the first slug of tracer, radioactivities of the fluids produced at the oil wells are recorded by the use of especially constructed wellhead units comprising Geiger-Mueller tubes, high-voltage supplies, and cathode-follower output circuits. Power is supplied to each wellhead from a centrally located radiation-instruments truck over four-conductor cables. Current pulses from the Geiger-tube output circuits travel from the wellheads to the truck over the same cables and are integrated by count-rate meters with the outputs fed into strip-chart recorders. Recording is continued until satisfactory records of tracer production are obtained in all wells or until data indicate that the flow of injected water from the particular input well is directional and that the tracer probably will not appear at some wells.

Second slug. The second slug of tracer is injected at a convenient predetermined time interval after the first. The quantity of tracer used is selected according to the sensitivity of the detection apparatus, the expected dilution, and the expected loss of tracer in the formation. As the second slug of tracer is produced into the oil wells, gamma-ray logs again are made to determine water-production profiles.

In some instances flow between wells may be directional to the extent that essentially no water from a given input well will be produced at some of the adjacent production wells. Also, injected water may by-pass adjacent wells and appear at wells more distant from the point of injection.

Technique Variations

A variation of tracer technique to evaluate such situations may be made by injecting radioisotopes with different gamma energies at more than one input well. By using a gamma-ray spectrometer in the radiation-instruments truck, the presence of more than one tracer may be determined by the gamma spectra, proportional to the energies of the emitted gamma rays. This measurement may be made on a semiquantitative basis and may be sup-

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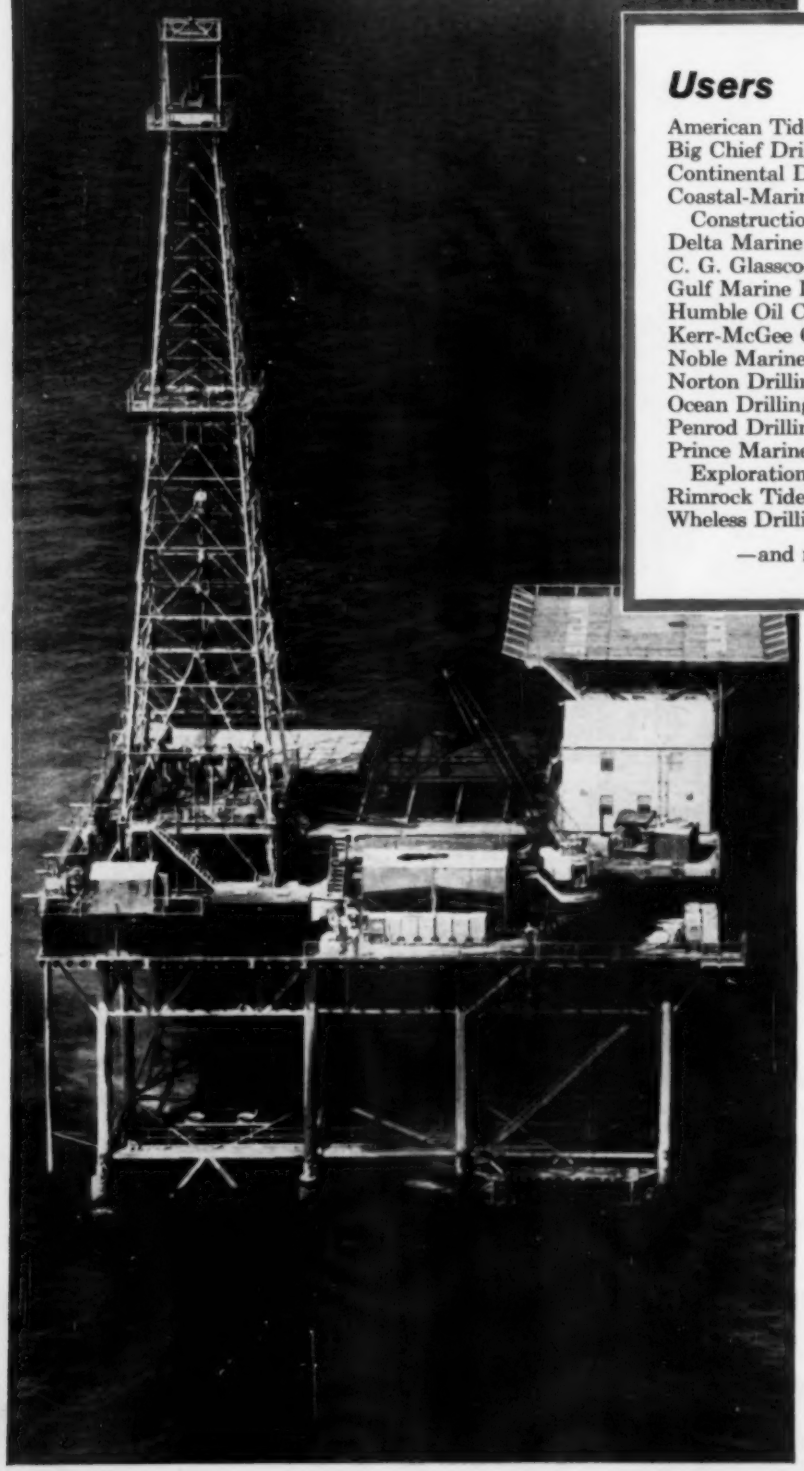

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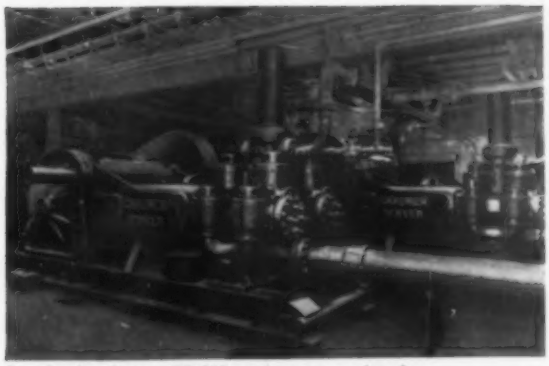
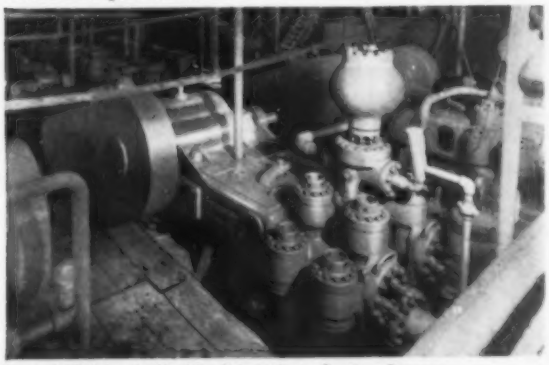
Ocean Drilling and Exploration Company's *Margaret* has a GXQ and two GXR pumps.



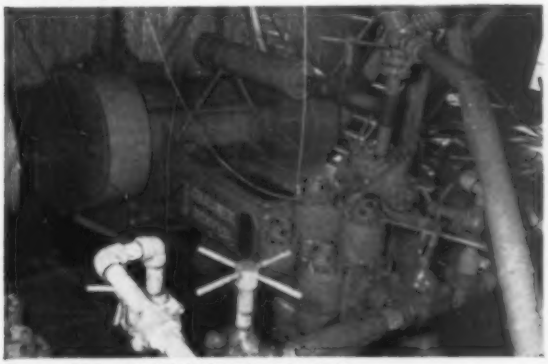
Two Gardner-Denver GR-GXR mud pumps on American Tidelands Barge No. 101.

Continental Drilling barge at Lake Pontchartrain and its GX mud pump.



Rimrock Tidelands Rig No. 3 has three Gardner-Denver GX mud pumps.

Gardner-Denver Model GXR on Glasscock Drilling Company's Rig No. 6.



Gardner-Denver Model GXR mud pump on the Big Chief Drilling Rig No. 34.

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plemented to yield a more quantitative measurement by determining the rates at which the respective radioisotopes decay.

Before this variation of the tracer technique may be employed, it should be determined that the sorption characteristics of the tracers are nearly the same to avoid errors caused by marked differences in transit times because of variations in the adsorption and desorption of the tracers. This determination may be made in the field by injecting two or more tracers simultaneously at one input well and identifying the tracers present in produced water by using gamma-ray spectrometry.

EXPERIMENTAL RESULTS

Application of radioactive-tracer techniques to field problems is illustrated herein for an inverted 5-spot making up part of a pattern waterflood in a northeastern Kansas field. The producing formation is a "shoestring" Pennsylvanian sandstone at a subsurface depth of approximately 850 ft.

A map of a section of the waterflood property is shown in Fig. 1. Injection rates are given in barrels per day at the right and the injection pressures in psig at the left of each input-well symbol. Fluid-production rates are given in barrels per day at the right of each production-well symbol, with oil the upper figure and water the lower one. Wells selected for testing are indicated by the outlined area. Core-analysis data were available for input Well E. The core cut from that well had an effective permeability (to water) ranging from a value of "impermeable" to about 26 md. The average effective permeability was 2.3 md; the average porosity was 17.3 percent.

Injection Effects

The rates of water injection and liquid production indicated that the water injected into Well E was probably being produced, at least in part, from wells 3, 4, 6, and 7. Well 5 had been abandoned and presumably plugged. At the time of the test, however, it was producing about 15 bbl of water daily, supposedly coming either from input Well E or F. Input wells B and C, because of the low injection rates, apparently were having little effect on the waterflood. Surrounding input wells A, D, G, H, I, and F probably were transmitting some water to the four production wells 3, 4, 6, and 7, although only Well H was taking a quantity of water comparable to that being injected into Well E.

A total of 93 bbl of water daily was being injected into Well E, whereas 120.6 bbl of liquid was produced daily

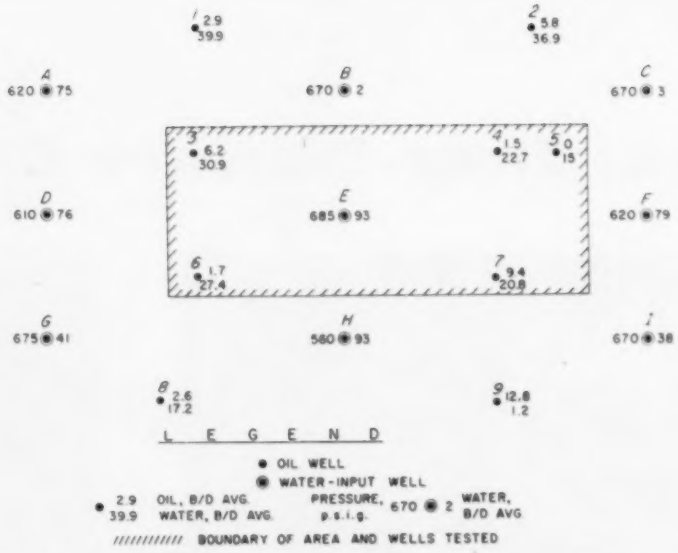

FIG. 1. Partial map of the described waterflood, showing water-injection and liquid production data on this Anderson County, Kansas, lease.

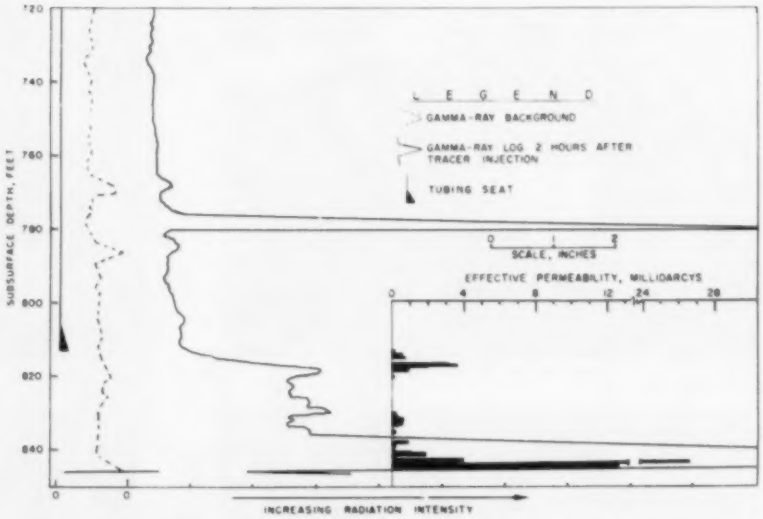

FIG. 2. Two logs are run. Gamma-ray background and input-profile logs and laboratory permeability profile for water-input Well E are shown here.

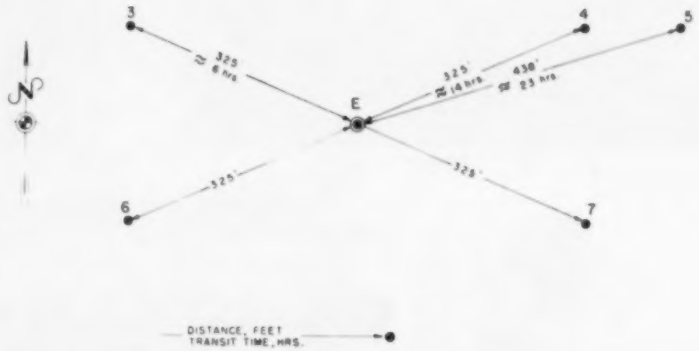

FIG. 3. Location and spacing of wells and transit time of tracer between wells are shown in this Anderson County, Kansas, field radioactive tracer test.

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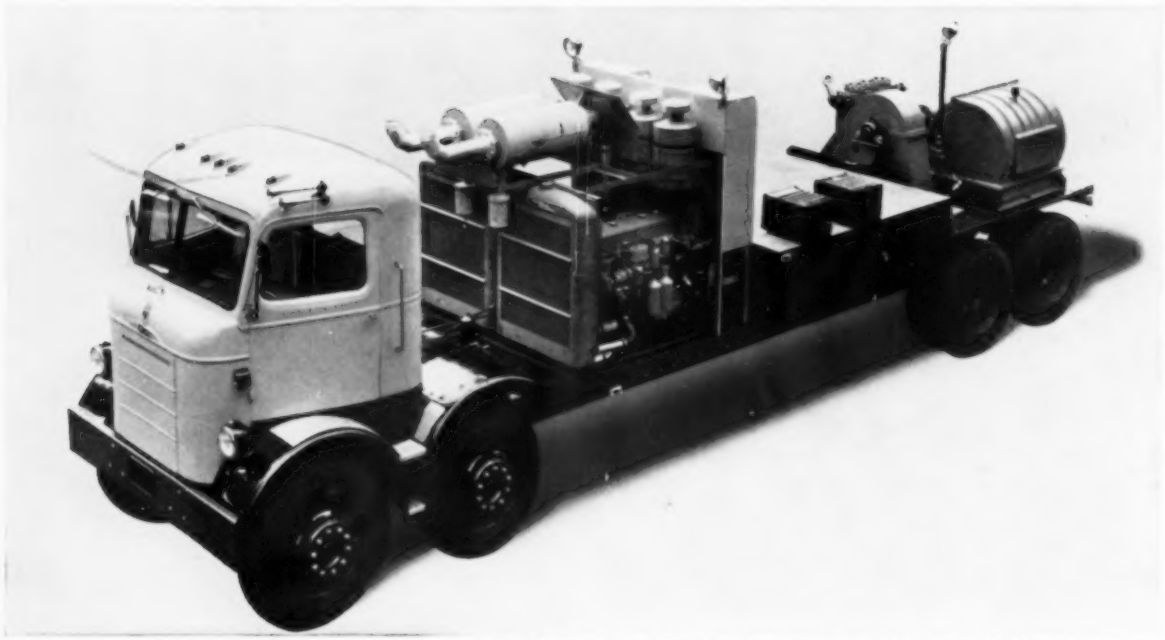

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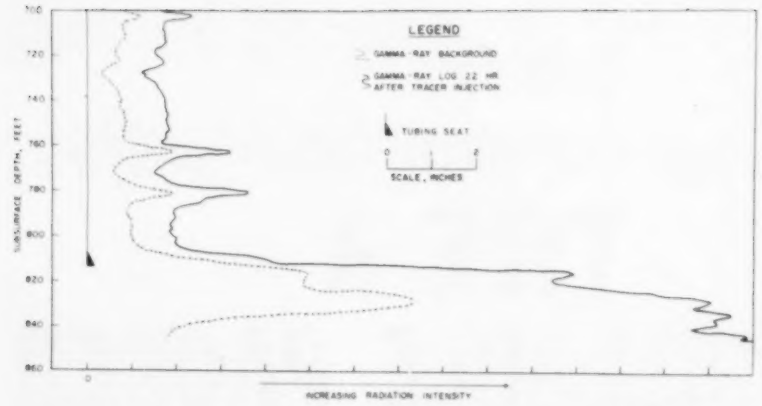

FIG. 4. **Gamma-ray** background and water-production profile logs of Well No. 3 in this Kansas field test records extreme radiation intensity.

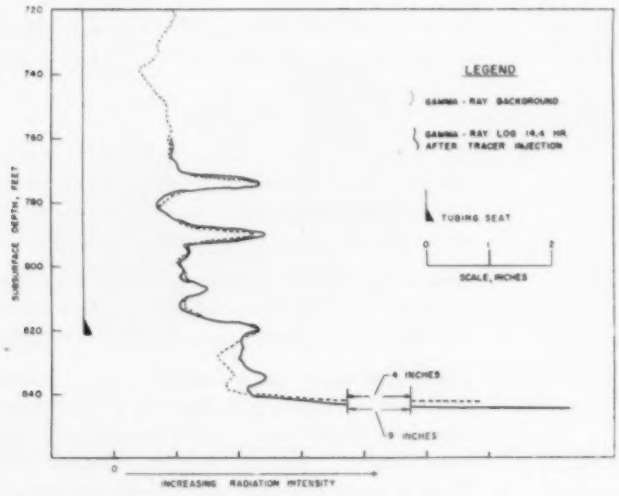

FIG. 5. **Well No. 4** made these gamma-ray background and water-production profile logs.

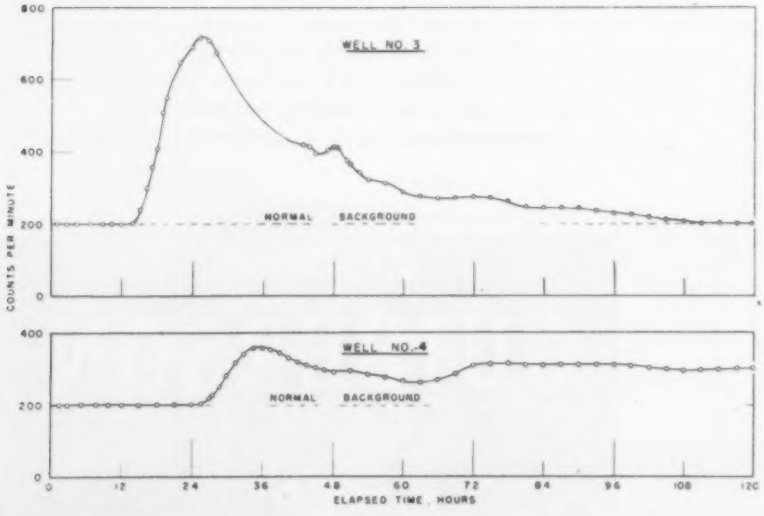

FIG. 6. **Recorded radioactivity** of water from production Wells 3 and 4 in the field radioactive tracer test.

at the four surrounding production wells. Total liquid produced included 101.8 bbl of water and only 18.8 bbl of oil, which indicated that the sweep efficiency of the injected water was low.

Input Profile

A radioactivity input profile was made in Well E, employing radon adsorbed on sized charcoal. Results of the input profile log, as compared with the gamma-ray background log and a plot of the effective permeability from core-analysis data, are given in Fig. 2. The input profile indicated that a significant portion of the injected water was leaving the well, presumably through a pipe leak, at a subsurface depth of about 778 ft. This zone was about 36 ft above the tubing seat. The water being lost at that point possibly was moving through a sand-shale lamination, acting as a "thief" zone.

Despite the loss of water at that point, however, other zones of exit from the well were indicated, the major secondary zone being between 843 and 845 ft, or about one foot above the bottom of the well. Other minor zones of exit were indicated at about 819 ft and between 825 and 830 ft. It may be seen that these zones coincide with indicated zones of high effective permeability as determined from core analyses (Fig. 2).

Well Recompletion

Input Well E was recompleted by the operator by running a string of 2-in. tubing from the surface to a depth of 814 ft, opposite the original tubing packer. The small pipe string was placed concentrically within the original 4-in. tubing and isolated from it at the bottom by a "hook-wall" packer. Pressure tests of the 2-in. string indicated that the annular space had been sealed off.

Time Lapse

About two weeks was allowed for the injection rate and pressure of Well E to stabilize. A tracer slug, consisting of about 60 millicuries of iodine 131 as potassium iodide, was injected into input Well E to determine transit times and distribution of water between wells.

A second slug of tracer, consisting of about 93 millicuries of radioactivity was detected in the water produced from Well 3 after about 14 hours. When allowance was made for the flow of the tracer down the input-well tubing and up the production-well tubing, a transit time through the formation of about six hours was indicated, as shown on Fig. 3. The radioactivity of the water produced into Well 3 was quite high and unmistakably showed

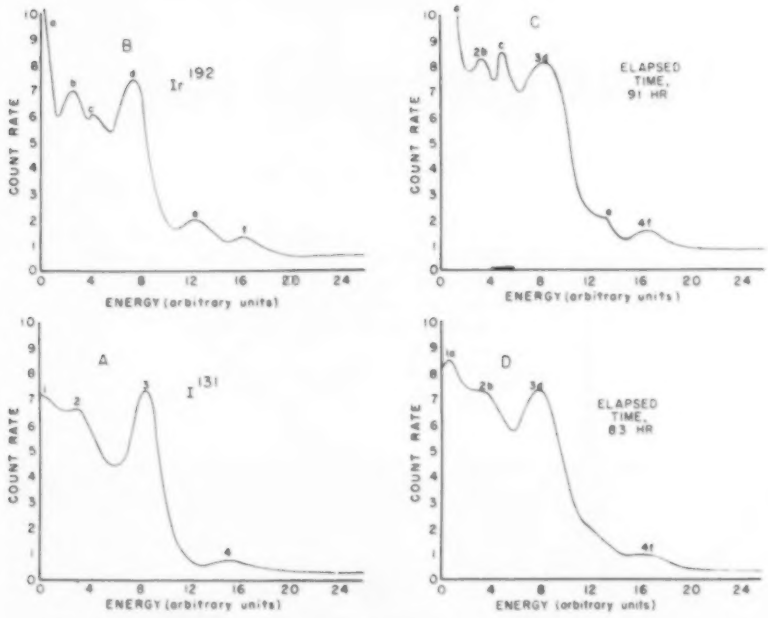

FIG. 7. **Comparisons** may be made of these gamma-ray spectra of iodine 131, iridium 192, and radioactive tracer produced with water from oil well.

that the water was entering principally through zones at depths of about 838 and 844 ft, as indicated by the gamma-ray logs shown in Fig. 4.

Increased radioactivity was detected in the water produced into Well 4 after about 24 hours, equivalent to a transit time through the formation of about 14 hours. The gamma-ray logs reproduced in Fig. 5 show the principal zones of entry of produced water into Well 4 as being at depths of about 835 and 850 ft, or at the bottom of the well. The increased radioactivity above background of the water produced into Well 4 was not nearly so great as that of the water produced into Well 3. In Fig. 6, the radioactivities of liquid samples obtained from the two wells are plotted against elapsed time after tracer injection. It may be seen that considerably more of the tracer appeared in Well 3 than in Well 4.

In both tests tracer was detected at Well 5, indicating that the water being produced from that well also was moving through the productive formation. No increases in the radioactivity of the water produced from Wells 6 or 7 were detected.

Two Tracers Used

The use of the gamma-ray spectrometer in distinguishing between different radioisotopes in common solution is demonstrated by data derived from another field tracer test. In that test both iodine 131 as potassium iodide and iridium 192 as sodium chloroiridate were injected into the same input well to determine their comparative utility as tracers.

The two tracers were used both in the primary injection and in the later secondary injection, which were about five days apart. In the first injection iodine 131 was used first, followed by iridium 192 about three hours later. The peaks of radioactivity detected in production-well fluids were so close together that the interval between injections of the two tracers was increased to 26 hours for the second injection. The peaks of detected radioactivity as the second slugs of tracer were produced occurred at about 28-hour intervals.

Fig. 7 shows gamma-ray spectra of iodine 131 (A), and iridium 192 (B), and the water produced from one production well 91 hours after injection of the first slug of tracer, at the resultant peak of radioactivity in produced fluids (C) and 83 hours after injection of the second slug of iodine 131, at the beginning of the radioactivity increase caused by the production of that tracer slug (D).

Principal peaks of gamma energy are indicated by letters for iridium 192 (Fig. 7-B) and by numbers for iodine 131 (Fig. 7-A). The energy peaks in the two plots of gamma spectra of produced water are correlated to those of the two reference radioisotopes by a combination of numbers and letters. In plot C the presence of both iodine 131 and iridium 192 is clearly indicated by energy peaks 2b, 3d, and 4f. Distinctive iridium peaks are shown at c and e. Correlation of that spectrum with data derived from decay measurements indicated that the radioactivity of the sample of produced water was caused by about 85 percent iodine 131 and 15 percent iridium 192. In plot D only very slight indications of the presence of iridium 192 are given by the peaks 1a, 2b, 3d, and 4f. Energy peaks c and e are not distinguishable in this plot. Decay measurements indicated that essentially all of the radioactivity in this sample was caused by the presence of iodine 131.

FIELD RESULTS

Based upon the field data presented, it was concluded that the water drive from input Well E (Fig. 1) was being exerted directionally toward wells to the north and northeast and that little, if any, water was moving toward production wells south of the input well. Therefore, much of the area between wells was not being swept by the flood water. Furthermore, correlation of the input and production profiles indicated that the water from input Well E was moving toward at least two, and possibly three production wells through a fracture system near the bottoms of the wells. Although this zone coincided with the zone of greatest effective permeability, the rapidity of transmission of the water demonstrated that it was not moving through the pores of a "watered-out" sand section. Plugging back those wells to a depth several feet less should result in increased flooding efficiency and oil production. This conclusion has been borne out by selective plugging by the producer and operator of wells on the property with similar characteristics.

Acknowledgment

The authors are grateful to the Salmon Oil Company for permission to publish the field data included in this paper and to Well Surveys, Inc., for cooperation in making gamma-ray, input-profile, and production-profile logs.

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HURRICANES

Their Force, Formation and Forecasting

Part 2

Hurricane Motion and its Forecasting

- Factors determining hurricane tracks
- Methods of 24-hour prediction
- Methods of 72-hour prediction
- Seasonal prediction of probable storm tracks

Dr. Herbert Riehl,
The University of Chicago
Chicago, Illinois

USUALLY the hurricane is a small circulation compared to the surrounding features of the flow. The subtropical high-pressure cells (or anticyclones), in particular, guide or "steer" a hurricane along their periphery. Thus, the average hurricane track forms an arc resembling a parabola (Fig. 16). The relation between hurricane and subtropical anticyclone is comparable to that observed between bodies such as earth and moon. Both rotate about a common center of rotation which, because of the large mass of the earth, is located inside the earth. Similarly, the common center of rotation of hurricane and anticyclone normally lies close to the central area of the anticyclone which is very little affected by the hurricane.

Factors Determining Hurricane Tracks

Forecasting problems do not arise in general from the hurricane itself, although occasionally storms grow to proportions that cause a marked displacement of the subtropical anticyclone, which in turn modifies the hurricane track (Fig. 17). Most deviations from average in the path of a cyclone result from changes in the large-scale middle latitude circulations. Their extent is comparable to that of the subtropical anticyclone and therefore they can displace, strengthen or weaken this center of action. Consider Fig. 18 which illustrates a difficult, yet frequent situation in the eastern Gulf. A hurricane is rounding the western extremity of the subtropical anticyclone of the Atlantic. Considering this anticyclone and the previous path of the hurricane, one can predict that the storm will cross the western Florida Coast.

A second anticyclone, however, has been advancing eastward across the southern U. S., and it has penetrated so far that it may become the predominant center guiding the hurricane. Extrapolation then fails; the path will undergo a drastic change. A sharp bend toward northwest or even west-northwest will occur, and the hurricane is likely to skirt the entire Gulf Coast to cross inland in Texas.

Fig. 19 shows another typical sequence. A storm is moving northward gradually in the western Gulf, again steered along the western edge of the Atlantic subtropical anticyclone which in this case reaches all the way across the Gulf. Normally one would expect an entry between Corpus Christi and Galveston. A strong westerly wave, however, is advancing from the Rockies, and as it reaches the eastern side of the mountains, the subtropical anticyclone is forced southward. This changes the steering of the hurricane from a southerly to a southwesterly direction. The storm recurves sharply and enters in Louisiana.

Sometimes the westbound leg of a path does not occur at all. This happens with preference in the Gulf and in the western Caribbean early and late in the hurricane season. Upon formation, the storm is already situated on the western edge of the subtropical anticyclone, and hence moves northward to northeastward from the start.

Two Hurricanes

Finally, Fig. 20-21 depicts an interesting situation, rare in the Atlantic but common in the Pacific, when two hurricanes are present in fairly close proximity, i.e. less than about 1000 miles apart. Following the idea of vortex inter-action, the two centers will rotate counterclockwise about each other, commonly about the midpoint of the axis that connects them because in such cases the two vortices usually have about equal mass and rate of rotation. At the same time, the influence of the subtropical anticyclone causes the pair to drift northward.

Using the foregoing type of reasoning, practically all storm tracks can be explained, even though some of them have a very involved appearance. The factors responsible for tracks and track changes are quite evident, and the real problem in forecasting consists in predicting what will happen to the circu-

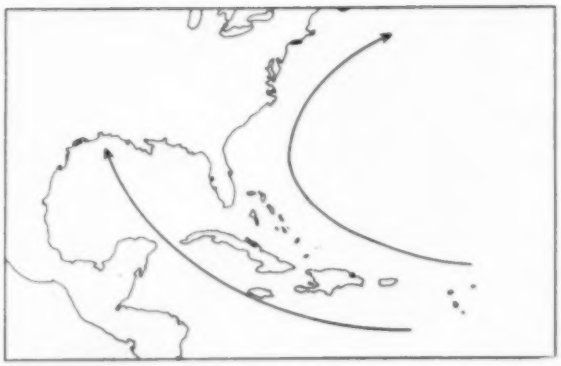

FIG. 16. **Hurricane tracks** in the Gulf of Mexico and along the Atlantic Coast follow these generalized paths in the middle of the season.

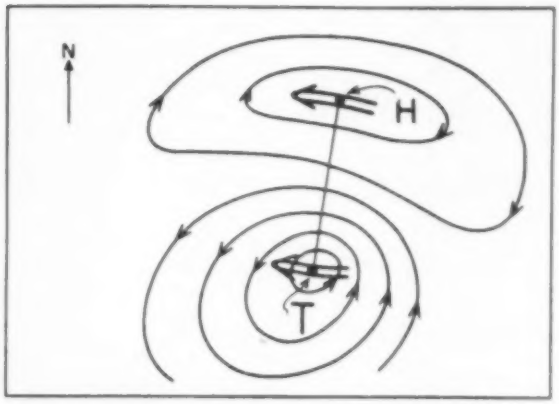

FIG. 17. **Displacement of sub-tropical highs,** or anticyclones as shown here, affects the movement by the large tropical storm to the south.

lations surrounding a storm. This is the main reason why observations from the periphery are so much more important for prediction than observations in a storm's interior. Lack of adequate data to make a proper analysis of features such as the subtropical anticyclone has been one source of technical failures in hurricane forecasting. The other main source is incorrect assessment of the impending changes in the broad circulation patterns.

Methods of 24-Hour Prediction

A limit of accuracy of 60 miles is probably the best one can do at present in statistical forecasts, because storm center positions along the tracks available for developing forecast methods are known at best within 30 miles over the ocean. This means that a 24-hour track may be in error by 60 miles merely due to uncertainties in positioning; one suspects that in many cases it is much more. Considerably greater accuracy has been claimed for center positions obtained recently with reconnaissance planes and radar. Detailed inspection of the records along individual paths, however, indicate that the current accuracy of center fixes is at most 10 to 15 miles. This should really be regarded as a high achievement, since it is questionable whether the storm center can physically be defined within narrower limits in many cases when the eye is large.

Climatology. When a storm travels over regions largely devoid of upper-air observations, a forecast based on a climatological study of past occurrences in the particular area furnishes the only practicable approach for issuing warnings. A probability factor can be included in such warnings to indicate the chances of success within 60 miles or within any other specified limit. It is necessary to forecast with this technique over large portions of the Atlantic. Of course, the method would be useful anywhere as long as it predicted with sufficient accuracy. Unfortunately, the probability of verification is very low in the Gulf and in the Atlantic off the southeastern U. S.

Extrapolation of past track. This is the main tool of the practicing forecaster, past and present. Essentially it is assumed that the flow pattern around a storm will not change much over the forecast interval, or that it will continue to change as in the past. Fig. 22 illustrates several types of extrapolation made in routine prediction. The last of these (e) is of higher order than the others. It makes use of the fact that after rounding the western edge of the subtropical high (point of recurvature) storms usually accelerate as they enter into the middle latitude westerlies.

Extrapolation normally is successful as long as a storm travels westward to northwestward in the trades. Since these situations encompass the bulk of cases that occur, extrapolation has a high percent verification. In the center and northern Gulf and comparable latitudes in the Atlantic, extrapolation becomes a poor tool since it is here that the "irregular" tracks occur most often.

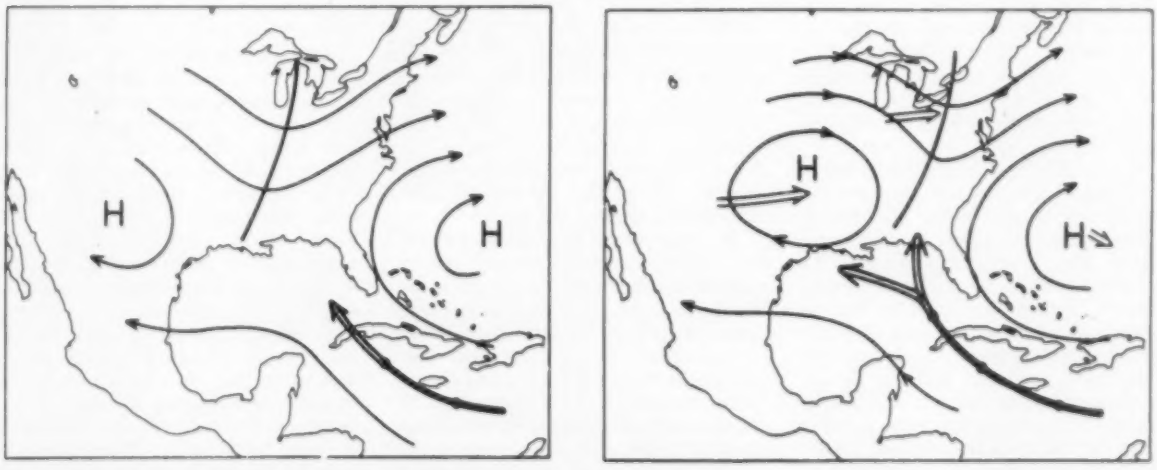

FIG 18. **Flow between 10,000 and 20,000 ft altitude.** (a) Approach of the hurricane toward the Gulf Coast follows this path (double arrow gives 24-hour extrapolation) until (b) one day later, the advancing high eastward in the U. S. causes a sudden path shift from its original course toward Texas.

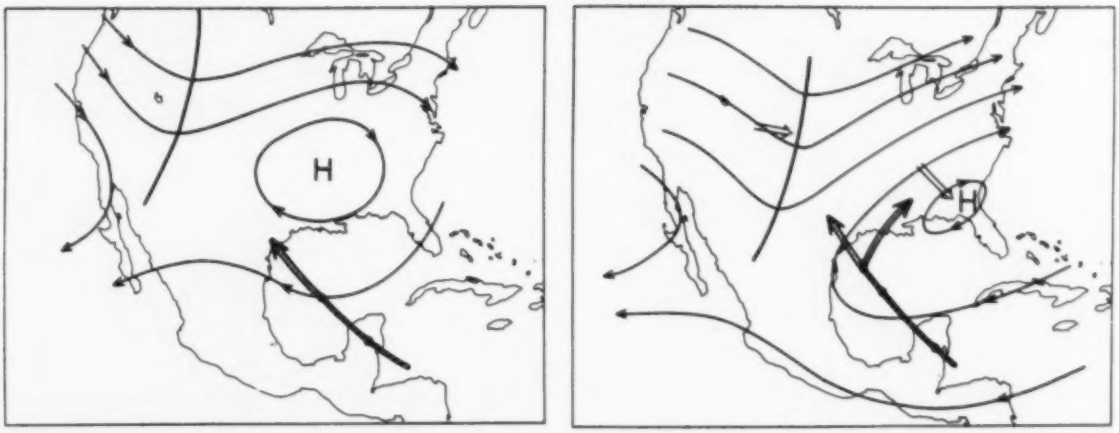

FIG.19. **Texas-bound hurricane** (a) shifts suddenly under the influence of a trough in the westerlies advancing from the Rockies (b). These charts are based on air flow between 10,000 and 20,000 ft altitude. Time lapse between (a) and (b) is 12 hours.

Extrapolation may also miss tracks that follow the average storm path quite well.

In August 1956, for instance, a hurricane (Betsy) moved toward Florida on a northwesterly path. With radar coverage and aircraft reconnaissance in the center going full steam, extrapolation put the center into Florida. But the situation developed as in Fig. 19. A trough in the westerlies advanced eastward in the U. S. from the Great Lakes with some intensification. The Atlantic subtropical anticyclone fell back toward southeast, and the hurricane curved toward the North Atlantic well to the east of the U. S. coast. Thus, the key to the situation was not at all in observations around the center or in radar trained on the center, but in data showing the evolution of the weather pattern from Chicago to New York.

Experience forecasting. Forecasters active in hurricane work over the years have become familiar with sequences such as Fig. 16 through 21 show; they try to modify the extrapolated path to agree with the dictates of experience. When the analog is correct, the forecast of course succeeds. Much present-day research is devoted to the task of solidifying the forecast experience in terms of numbers.

Experience forecasting incorporates one tool which does not enter into extrapolation or any of the quantitative methods of prediction currently under study. This is geography. Ideally, the researcher wishes to produce a method that is applicable anywhere. But in forecasting for coastal areas, a variety of local factors enter that do produce deviations from the path to be expected over open ocean. Notably, hurricanes will remain over water as far as possible; thus in going from the Caribbean to the Atlantic or Gulf, the majority pass through the Mona and Windward passages, and the Yucatan

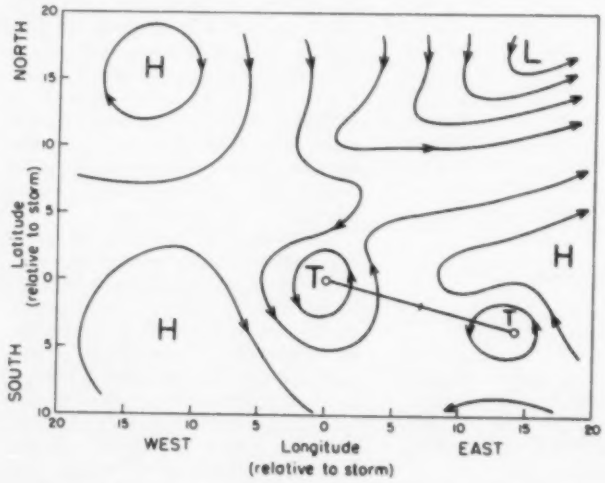

FIG. 20. **Flow** near 20,000 ft altitude in the middle Atlantic, September 5, 1950, charts two hurricanes.

Channel, where storm tracks are quite concentrated. The Rocky Mountains have a marked effect on the air currents crossing the western states, and hence they influence the path of the storms subject to steering by these currents. This is especially true for hurricanes off the Texas Coast. Methods for modifying general forecasts on the basis of regional peculiarities probably can be devised, but work along such lines is very limited at present.

Box calculation. Utilizing flow charts of the middle of the troposphere by weight, measurements have been made of the currents affecting a storm over areas sufficiently large to incorporate displacements of the large-scale flow pattern, yet not so large as to extend into extraneous circulations. Fig. 23 shows a typical example. Winds measured over the area are related to the storm displacement by a regression formula; the size of the area used in the final form was determined through trial and error. In several testing samples from Atlantic and Pacific oceans over 80 percent of the cases verified within 60 miles.

Experimentation with the method in some actual cases has shown that the computation is quite sensitive to the way the initial chart is drawn in forecast offices. When data were fairly abundant and the charts analyzed with care, verification was good. On days with little data, however, different forecast centers arrived at widely differing analyses of the charts, and hence they obtained varying results from the computations. Obviously, no formula can yield the right answer unless the input data are correct. If enough observations existed, the problem could be sidestepped by basing all forecasts directly on the observations, eliminating the need for an analyst. Such a scheme may be feasible for hurricanes in the Gulf, since a fair number of observation stations surround this body of

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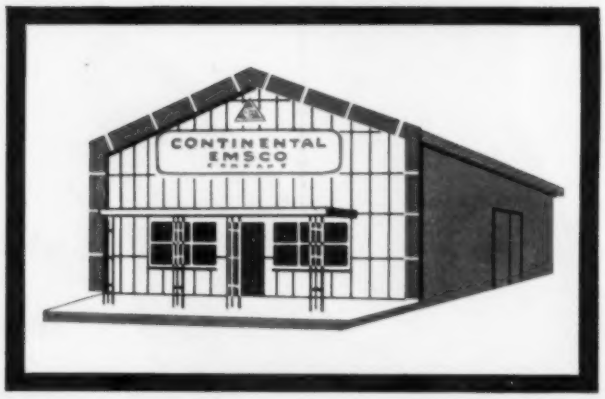

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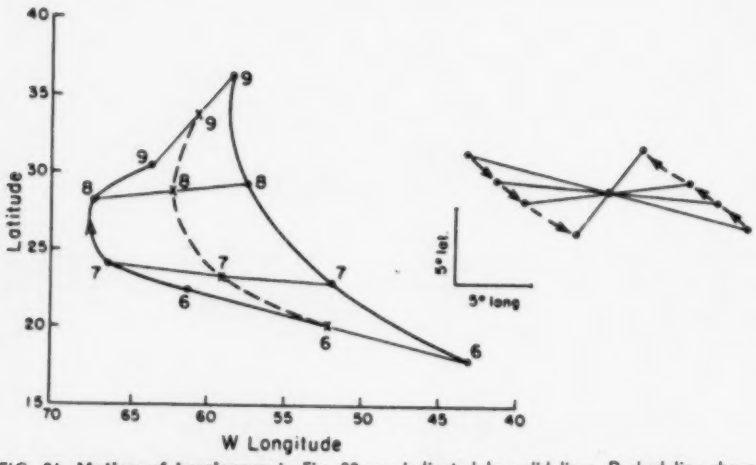

FIG. 21. **Motion of hurricanes** in Fig. 20 are indicated by solid lines. Dashed line shows midpoint of axis connecting them, September 6-9, 1950. At right is the motion of hurricanes relative to midpoint.

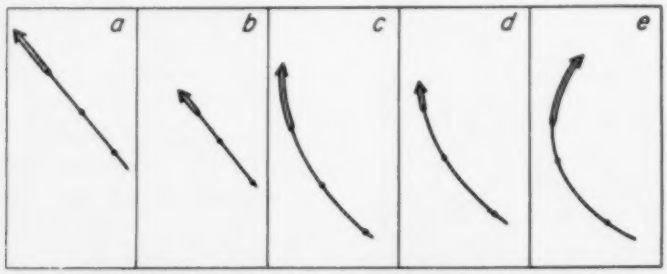

FIG. 22. **Five types** of 24-hour extrapolation of hurricane motion.

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water on all sides. As a general proposition this is not practical at present because hurricanes so often are situated in places far removed from a satisfactory number of upper-air stations. Hence it is necessary either to develop formulas insensitive to map analysis or to improve the analyses.

Physical prediction. Various attempts have been made since the end of World War II to write the general laws of motion in a form suitable for processing on electronic calculating machines, and to arrive at predicted flow patterns with a series of short time steps. For instance, the machine may make 24 one-hour predictions compared to the forecaster's single 24-hour step. If this is successful, any need to base hurricane forecasts on the initial map disappears, and the storm may be moved along hour by hour as the general map pattern evolved in the computer.

Methods of 72-Hour Prediction

This time interval has been chosen for discussion because it confronts the meteorologist with really a quite different problem from, say, 36 to 48-hour forecasting, with which forecasters try to cope by stretching the methods employed in one-day prediction. This simply cannot be done when a three-day prediction is desired. Not even a climatology had been made until 1956 when it was done; in this climatology, besides seasonal and latitudinal factors, a synoptic parameter was also included. Since current storm motion depends on the configuration of the flow patterns around a hurricane, the synoptic parameter was taken quite simply as the initial direction of storm motion itself. Mean three-day displacements were calculated in terms of initial latitude and initial direction of motion. Inclusion of more parameters would have been desirable, but the size of the sample did not permit this.

In addition to average displacement, the probability of verification within radii of 150, 300 and 450 miles from the actual displacements was also calculated. Considering the present situation with regard to 72-hour forecasts, a dependable verification within 150 miles would be a great advance indeed. The following was found. Climatological prediction will yield forecasts within 300 miles with a probability of 75 percent when a storm is located south of 20°N and is moving west to west-northwest. For storms in the Gulf or in the Atlantic north of 20°N and moving northwest to north—the most interesting class of cases — chances of verification are very poor as would be ex-

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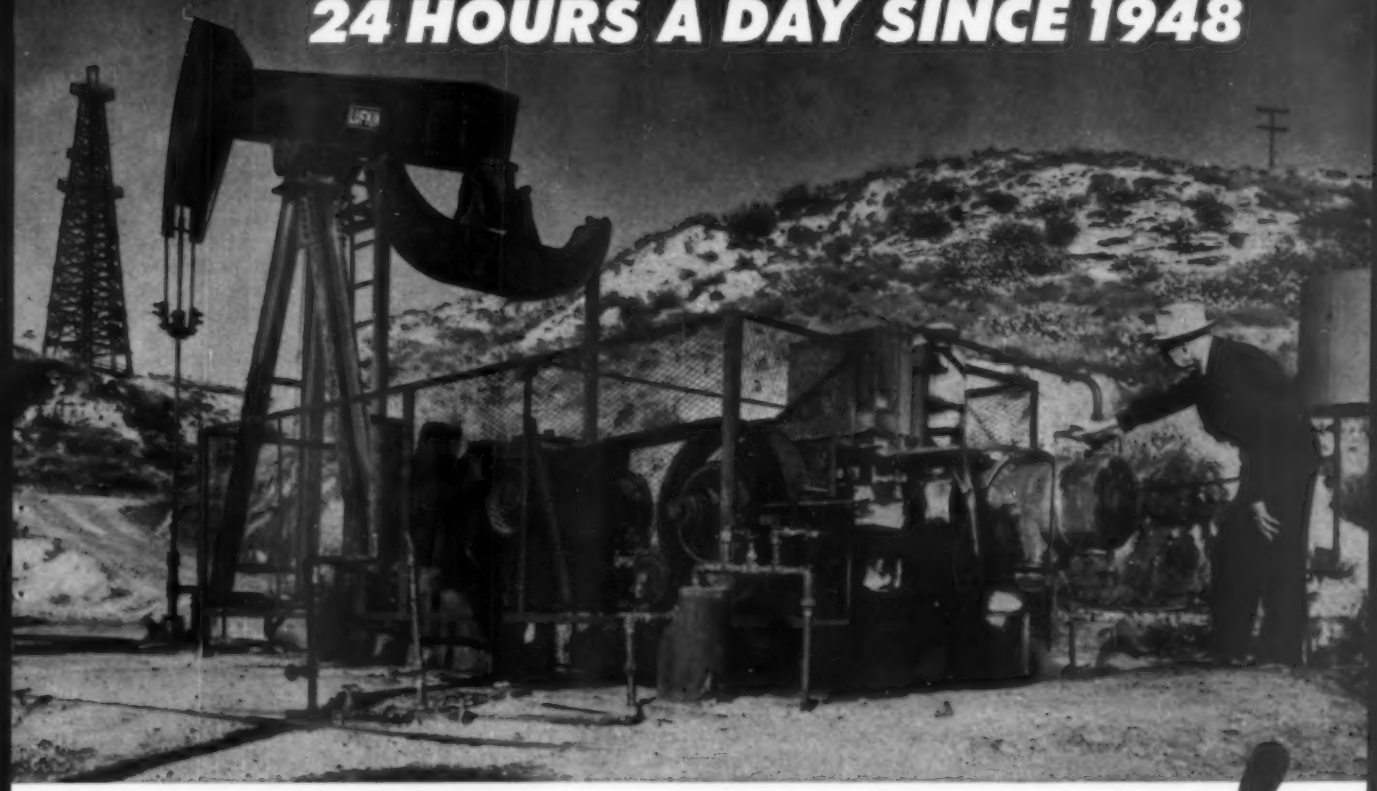

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pected from the diversity of track types in this latitude belt. Even in these situations, however, climatology has its uses — as best guess when one must forecast but has no other means for proceeding, and as yardstick to assess the quality of any forecast scheme.

It should be stressed that a climatological calculation is not something absolute, that climatologies can be produced from many viewpoints depending on what one wishes to determine. For instance, we may be interested only in the behavior of storms entering the Gulf or situated in the Gulf.

After finishing the climatic aspects of three-day motion, the main problem of forecasting the deviation of the individual storm track from the climatic mean must be tackled. This is very difficult, but in one respect the situation is better than in the case of the 24-hour forecasting. There is no doubt that the three-day motion is controlled by gross features of the broad circulation patterns in middle latitudes. Hence the problems of observation and analysis are minimized; there are sufficient data from North America and from the Atlantic and Pacific oceans to establish with certainty the gross features of the flow.

It may be worth noting that a regional approach could be attempted for three-day as well as for 24 or 48-hour prediction. Since three-day predictions depend on the middle latitude flow over large areas, chances of success do not appear very promising.

Seasonal Prediction

Fig. 17 through 21 have already shown the principle of behavior of hurricanes relative to the large-scale flow pattern. For instance, when a marked upper-air trough persists over the east-central U. S., hurricanes from the Atlantic will be drawn northward, toward New England or a little off the coast. When a trough persists on the East Coast or even farther east, storms will recurve well off the coast, and never pose a threat to the country. Again, when the easterlies extend farther north and west than average, storms from the Atlantic are likely to cross into the Gulf, but when westerlies are found at relatively low latitudes hurricanes will rarely follow such paths.

Is there anything one can say on a seasonal basis about the gross expected behavior of the storms to come?

When the flow patterns are averaged over a whole season, deviation of the pattern in the individual season from the 20-year mean does indicate that the general behavior of the storm tracks conforms to the models just described. More evidence is needed, but it is not probable that the correlations so far obtained will be completely upset. ★ ★

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Dry ice used to set temporary plug to repair faulty wellhead equipment

A "quick freeze" job made a routine job out of one that could have permanently damaged a well.

"Cold treatment" was applied to the master valve on the Christmas tree of Delhi-Taylor Oil Corporation's E. M. Card No. 1, a gas well in the McAllen field, Hidalgo County, Texas.

The unusual situation developed when H. R. Walker, the company's district superintendent at McAllen, found that the master valve on the well would not function.

Under normal procedure, the well would be killed with mud or water before attempting to remove and replace the malfunctioning valve. An attempt would then be made to bring back the well by running a swab in the tubing.

Swabbing a high-pressure well, as in the case of the Card No. 1, is a hazardous operation at best. Condition of the tubing was not known, since the well was drilled and completed in the mid-thirties by another operator and records on the well were hazy. It was known, however, that the original owner had cemented the 2½-in. tubing to the long string.

For these reasons, Delhi-Taylor did not know whether or not a swab could be run to an effective depth. Even so, if the swab should stick and tools be lost, there would be little chance of recovering the well, much less the swab.

At this point, it was suggested that the well be sealed off by freezing a solid block of ice inside the bottom portion of the wellhead equipment. Otis Pressure Controls engineers were consulted and the "deep freeze" procedure was devised.

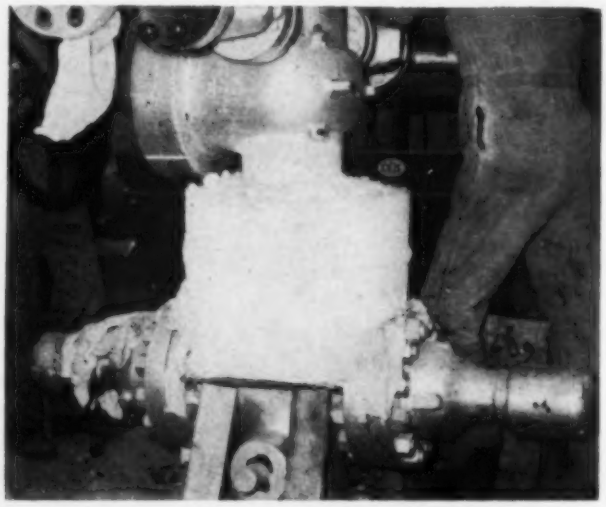
The tree consisted of a ram-type tubing control head, the faulty 7-in., series 900 flanged master valve, with normal wellhead equipment installed above.

A metal container was built around the wellhead equipment between the tubing head and master valve. The container was filled with dry ice and immediately a very thick, even slurry of bentonite and water (about two barrels) was pumped into the wellhead. After allowing the mixture to "freeze up" for 17 hours, a pumping truck safety-tested the plug to a pressure of 3000 psi.

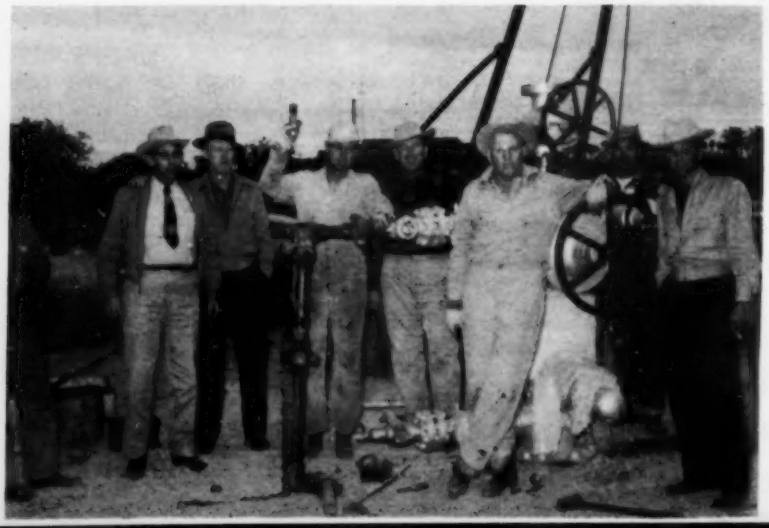
Wellhead equipment above the master valve was then removed and a new 3-in. master valve with adapter to 7-in. was installed above the old valve, and the tree assembly was then completed in normal fashion.

The plug melted in about 3½ hours and was released into the atmosphere through a ¼-in. choke. Equipment and personnel expense for the job was $500, exclusive of pumping and testing service expense. ★ ★ ★

An icy grip around the Christmas tree effectively sealed the South Texas well until a new valve was fitted above a faulty master valve. Before beginning work on the valve, the freeze plug was tested to 3000 psi.



Freeze Plug Frees Frozen Valve



All flanged up and all smiles after the successful operation. Shown here are oil well cementing company personnel, who pumped mud into the wellhead and tested strength of the plug, and Delhi-Taylor men who were responsible for the job.

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There's only one place to find out how best to treat your crude to meet pipeline requirements. And that's right on the lease.

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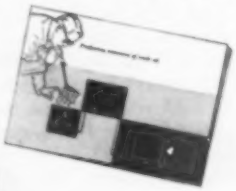
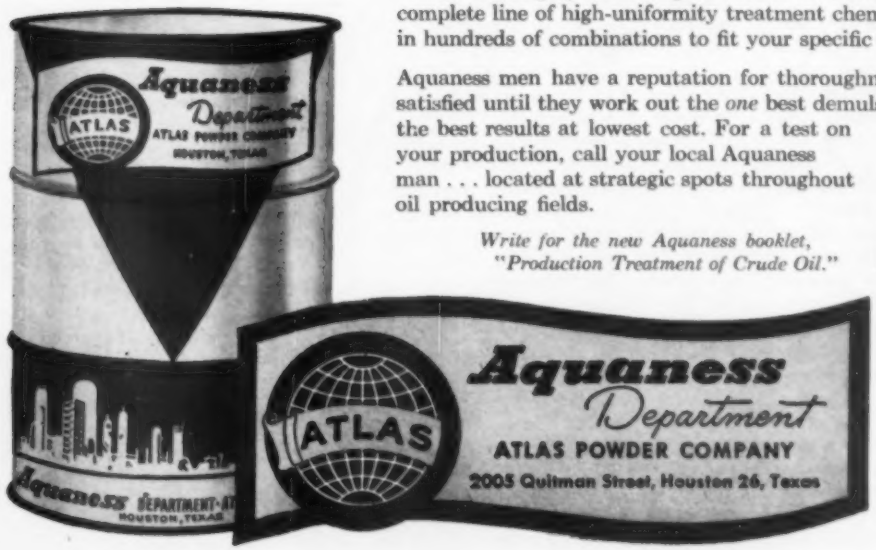


Write for the new Aquaness booklet, "Production Treatment of Crude Oil."



In well treatments, simulated field tests indicate that . . .

Pressure Drop Across Perforations can be COMPUTED

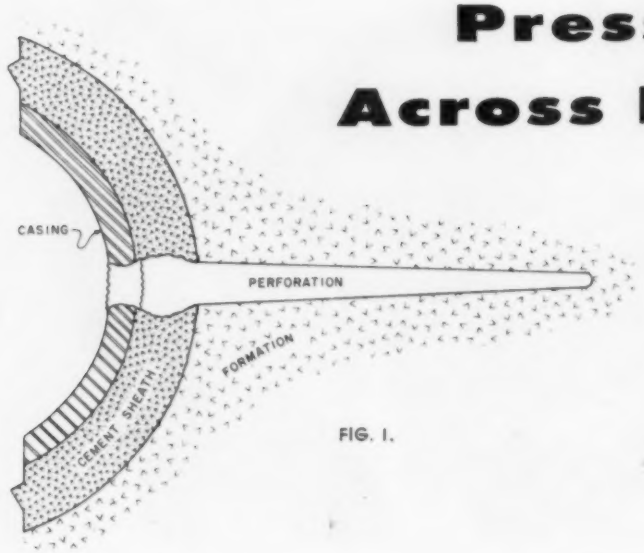


FIG. 1.

Friction losses in pipe plus pressure drop across perforations provide a more accurate estimation of hydraulic requirements in well treatments

Robert Wade Brown and Bruce Gilbert
The Western Company
Midland, Texas

THE trend toward higher injection rates in well treatments has amplified the effects of several factors which had previously been considered as unimportant. The first of these factors to be widely recognized was the pressure created by friction in the treating string.[1] Now another factor—the flow rate through casing perforations—has become important.

Theoretically, the capacity of a perforation to accept the flow of fluid is limited only when the "critical velocity" (the velocity of sound in the medium) is reached. Attaining this "critical velocity" through casing perforations is unlikely since the pressure required to develop a critical velocity is in excess of any pipe strength.

At fluid velocities less than critical, the flow-rate through a perforation is directly proportional to the pressure differential across the perforation. Therefore, in a practical sense, the flow capacity of a perforation is limited only by the pressure differential which exists across it.

A mathematical method for computing the pressure loss across a perforation has been devised and these calculations have been substantiated with experimental results. Data on the flow of fluids through jet perforations was obtained under simulated field conditions. High injection rates were attained by the use of four 600-hp pumping units and corresponding injection pressures were recorded by an electronic recorder. With this method for computing pressure loss, the flow capacity of any perforation of known area can be determined.

Concept of Method

In the orifice type flow, the main problem is to determine the contraction coefficient (C_c), the velocity coefficient (C_v), and ultimately the discharge coefficient (C_d). In perforation flow studies, individual values of C_c and C_v cannot be determined. Their product, C_d, can be computed for a particular set of conditions.

Under differing conditions of flow, the value of C_d is known to vary. The question is whether this variance is significant considering inaccuracies of field measurements. Some of these inherent inaccuracies involve field methods of determining injection rates, instantaneous sand concentrations, orifice shape and diameter, and even inside diameter of the casing string.

Some characteristics that tend to alter the C_d significantly include: (1) Roundness of upstream edges of perforations, (2) dimpling of the area adjacent to the perforation, (3) fluid viscosity, (4) "tube" flow, and (5) submerged discharge. (Ordinarily an increase in orifice diameter tends to decrease C_d. In the case under study, this effect is apparently offset by other factors.) Tube flow occurs when the wall thickness of the orifice is approximately two or three orifice diameters. Hence, the so-called tube flow would be considered only if the cement sheath behind the casing retained the dimensions of the perforating jet or bullet. Submerged discharge, such as the case would be under down-hole conditions, tends to increase the C_d by permitting tube flow to commence at a lesser orifice thickness. In submerged discharge, tube flow can occur at an orifice thickness less than one orifice diameter. For simplicity, the effects of submerged discharge are neglected in this paper.

Fig. 1 depicts a typical perforation. From this drawing it is apparent that the hole through the cement "bells" behind the casing. Hence, "tube" flow should not be considered. With typical orifices, roundness of the edges can increase the C_d value from 0.61 to 1.0. In the case of flow through perforations, this increase is to the range of from 0.8 to 1.0. The higher values (0.9 to 1.0) might be expected in bullet type perforations where a pronounced "dimpling" of the casing results. For jet perforations in general, the C_d value has been found to be between 0.8 and 0.9. (The experimental determination of this value is discussed later.)

Once this C_d value is determined, it may be used along with the casing velocity to determine the jet stream velocity according to the equation:

$$V_p = \frac{V_c \times A_c}{A_p \times C_d} \quad . \quad . \quad (1)$$

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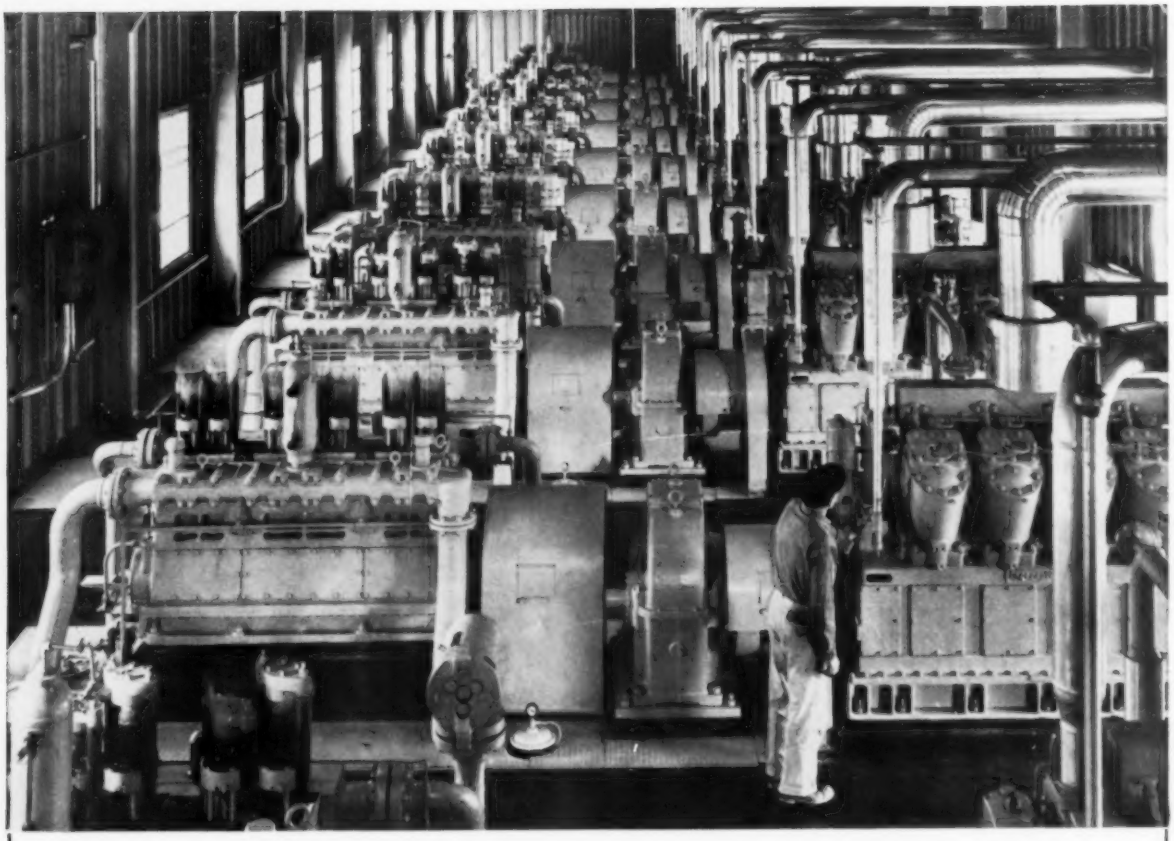

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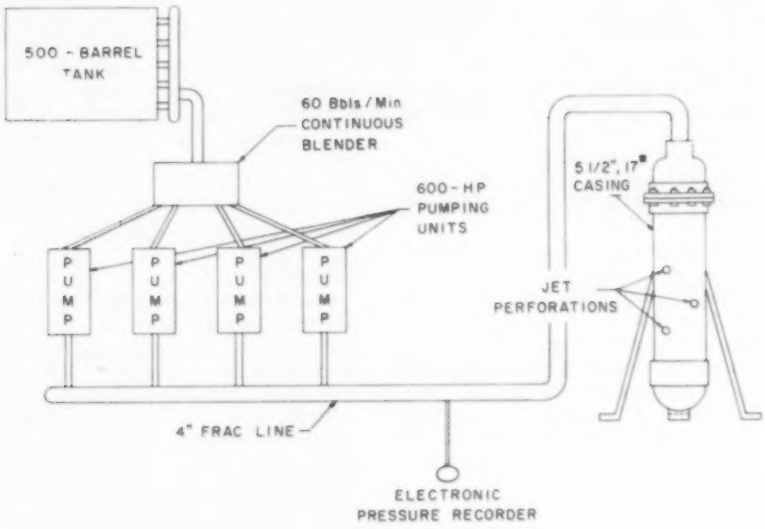

FIG. 2. **Experimental setup** to simulate field conditions of well treatment to provide data used to substantiate pressure drop calculations.

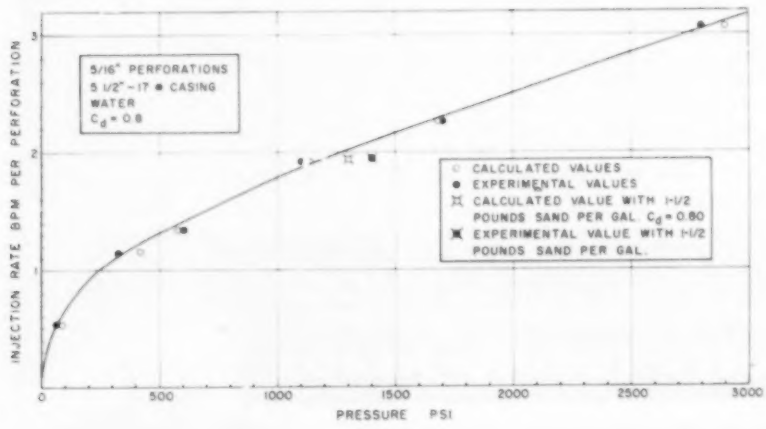

FIG. 3. **Pressure loss across perforations** is shown in this pressure loss vs rate curve of both experimental and computed values where computed values are based on a C_d of 0.8.

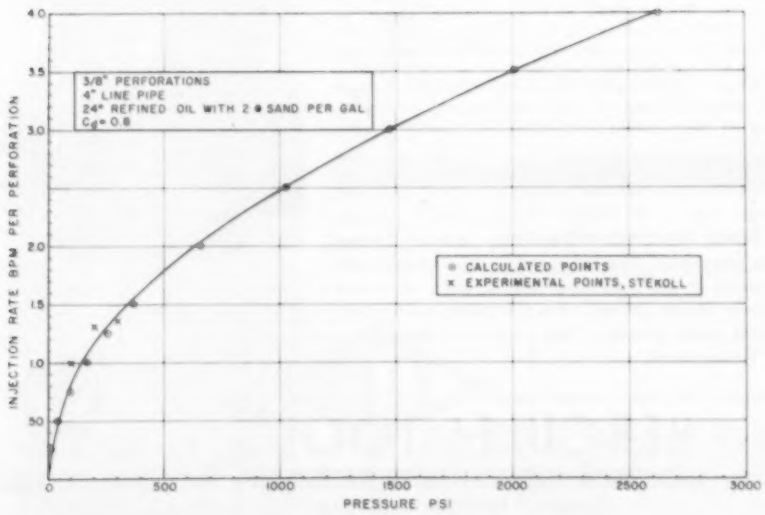

FIG. 4. **Comparative accuracy of method** is illustrated in this pressure loss vs rate curve for computed values and for those taken from Stekoll's data[3] for 2 lb of sand per gal of 24 deg API gravity refined oil.

Where V_p is the fluid velocity through the perforation, V_c is the velocity down the casing string, A_c is the cross-sectional area of the casing, A_p is the average estimated cross-sectional area of the perforations, and C_d is the discharge coefficient.

The calculated jet velocity (V_p) then may be used in the Bernouli constant energy equation to determine the pressure differential. The Bernouli equation simplified to field units is:

$$\Delta P = \frac{\rho}{149.4} (V_p^2 - V_c^2) \quad . \quad (2)$$

Where ΔP is in pounds per square inch, ρ is the specific gravity of the fluid, V_p and V_c are velocities in feet per second, and 149.4 is a conversion constant.

Experimental Data

A three-foot long, 5½-in., J-55, 17-lb casing nipple was plugged on one end and perforated with six jet charges (average hole diameter equal to 5/16-in.). Four 600-hp pumping units, supercharged by a 60 bbl per minute continuous blender, were used to pump water into the nipple. A constant pressure was maintained throughout each test. A corresponding injection rate was then correlated to each pressure. (Fig. 2 illustrates the equipment setup.)

These pressure-vs-rate values were plotted on a graph along with corresponding computed values. By trial and error in Equations 1 and 2 the C_d that correlated these results was determined to be 0.8. (This value of 0.8 has been substantiated with actual well treatments where the exact number of perforations open was known.) Fig. 3 shows the pressure-vs-rate curve of both the experimental and computed values where the computed values are based on a C_d of 0.8.

Only one experimental point, pressure-vs-rate, was determined for a sand-laden fluid. This point, along with the calculated value, is also plotted in Fig. 3. The seven percent variance between these values might be attributed to the variable or indeterminate sand concentration in the fluid. (The loss in pressure head at a given rate is directly proportional to the specific gravity, ρ, of the fluid.)

It is well to mention that the perforations showed no enlargement due to the passage of the sand-laden fluid even though the sand-laden fluid stream cut a piece of angle iron supporting the equipment. This would be expected since the C_d was determined to be substantially less than 1.0. (For a C_d appreciably less than 1.0, the contraction coefficient would be less than 1.0, in which case the diameter of the stream is less than the diameter of the hole.)

In order to carry this analysis one step further, the pressure loss-vs-rate values obtained by Marion Stekoll[3] were plotted along with computed values. These results are shown in Fig. 4. Stekoll's data were obtained from refined oil, 24-deg API, with 2 lb per gal of 20-40 mesh sand. The perforation was a ⅜-in. hole drilled in the wall of a 4-in. line pipe nipple. The agreement between Stekoll's experimental values and those calculated is evident.

Conclusions

Computing flow capacity. From data and material discussed, it is concluded that the loss in pressure due to flow through a perforation can be calculated with reasonable accuracy. If the pressure differential is known, flow capacity of the perforation can be calculated. For such calculations, a C_d value of 0.8 should be employed for jet perforations while a slightly larger value might be assumed for bullet-type perforations. The nature of a jet perforation is such that a C_d slightly higher than 0.8 could prevail in some cases.

A critical velocity is not possible due to pressure limitations of oilfield tubular goods. Therefore, the discussed equations and theory will hold throughout the pumping velocity range. At the critical velocity, the velocity of sound in the media (for water, sound travels

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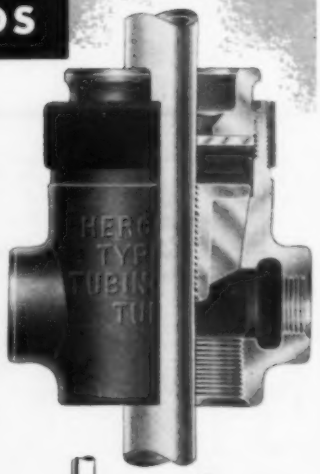

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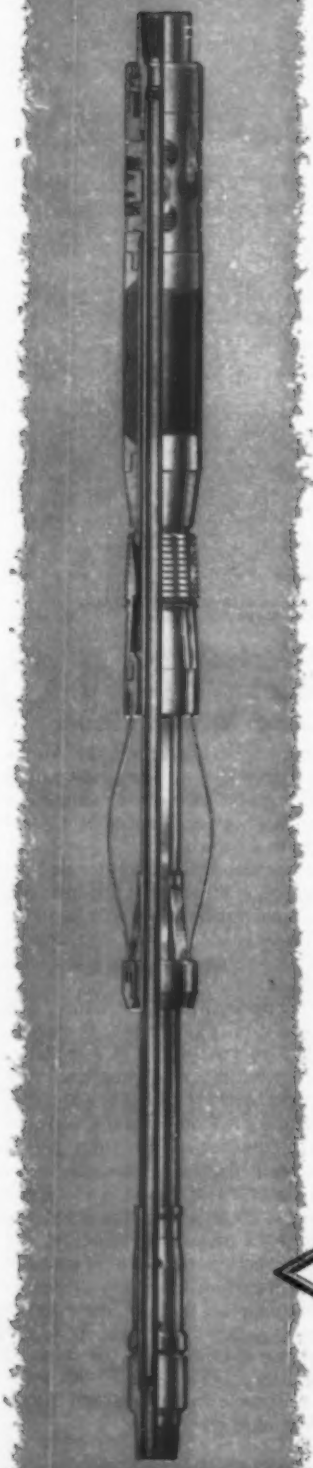

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at about 4700 ft per sec), decided changes occur within the flow patterns and the classical equations no longer hold true. At any flow less than critical, the fluid velocity varies directly with the pressure differential. This means, then, that a set capacity for a perforation may not be assumed unless the corresponding pressure is given and is held constant.

Since a low injection rate per perforation (less than one barrel per minute) will develop only a very small pressure head (less than 150 psi), it would be advantageous in many cases if the operator would control the number of open perforations which he must consider. This may be accomplished either during initial perforating or by the use of ball sealers when fracturing or acidizing.[4]

Acknowledgment

The authors are grateful to the management of The Western Company for permission to publish these findings.

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★ ★ ★

Creole Installs Aluminum Pipe In Lake Maracaibo

The floor of brackish Lake Maracaibo, Venezuela, will be crisscrossed with 22 miles of oil-carrying aluminum pipe, it has been announced by Creole Petroleum Corporation.

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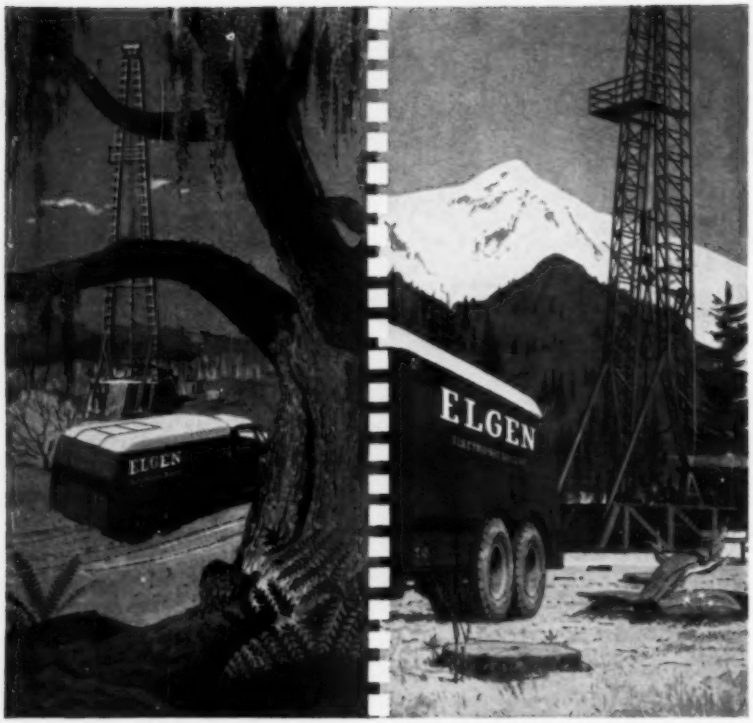

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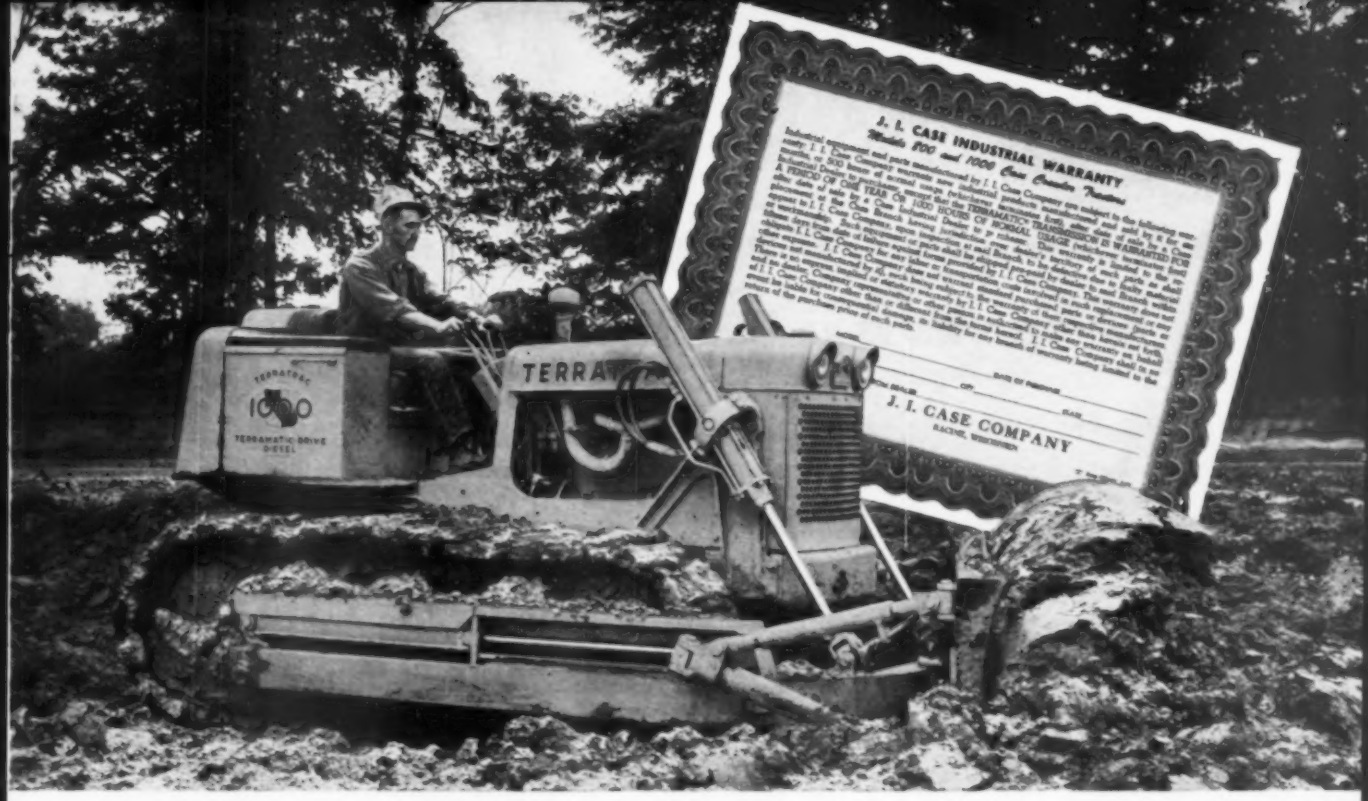

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BY providing a solid interface between the base of a column of liquid being lifted out of a well and the gas that does the lifting, a free piston gas lift device has increased gas production from 18 San Juan Basin wells by 36.2 percent. These wells were plagued by a relatively high connate water production that loaded up the tubing and actually throttled gas production. Formation pressures were not sufficient to completely flow out all the water produced, and in order to take advantage of the energy in the gas pressure to completely lift the produced water, the free piston was employed. Case histories of these 18 wells are more fully described later.

Prior practice. In gas wells that produced sufficient water (and/or condensate) at choked down production rates, it was common practice to complete such wells with a tubing string whose size was selected from a consideration of these factors:

1. The tubing should be small enough to provide sufficiently high velocities to carry out the water or condensate expected.
2. It should be large enough to avoid severe pressure drops that would reduce production unnecessarily.

The string was usually run with a packer near bottom and the annulus left full of mud. The production of bottom water in these circumstances, given a high enough gas stream velocity, was continuous in the form of a spray more finely dispersed towards the top. Separating the water and gas was attended by varying degrees of difficulty and cost.

In such a tubing string the pressure gradient of the gas flow alone is seldom a serious matter. However, the effect of water dispersed inside the tubing is relatively large and presents a very different picture.

If the gas flowing velocity decreases and becomes less able to lift water, the pressure gradient in the tubing then gets steeper and reduces the gas flow. So long as the formation is sufficiently competent, all that happens is that the bottom-hole pressure is raised, the production declines a little, and the pressure gradient in the tubing string becomes steeper.

This can progress to the point that the well will load up and die. This occurrence is usually anticipated by shutting off the supply line and opening the well to atmosphere so that the enormous increase in velocity will literally purge the tubing string and reduce its pressure gradient.

The economic optimum frequency of purging then becomes a compromise between the gas production loss due to the accumulation of water and the quantity of gas used to get rid of it. The water lifting efficiency is low because (although the gas velocity at the surface may be very high) the pressure gradient in the tubing is affected by the increased gas flowing velocity, and down at the bottom of the well where velocity is most needed, the gas pressure is not being reduced nearly as much as it is at the surface and there is still a very large slippage loss in the lifting of the water, especially with the larger tubing sizes.

When blow-down frequency becomes stable, the cycle can be made automatic by various available types of controllers. At best, the flow rate graph for such an installation has the shape usually known as "Saw Tooth." Where the delivery line pressure is a constant, the tubing head pressure varies very little and the rising gradient in the tubing demands a rising bottom-hole pressure, a diminishing formation-to-hole differential and production is reduced gradually until the next purge is made.

Typical Free Piston Installation

To introduce a free piston into a gas well producing through tubing, it is

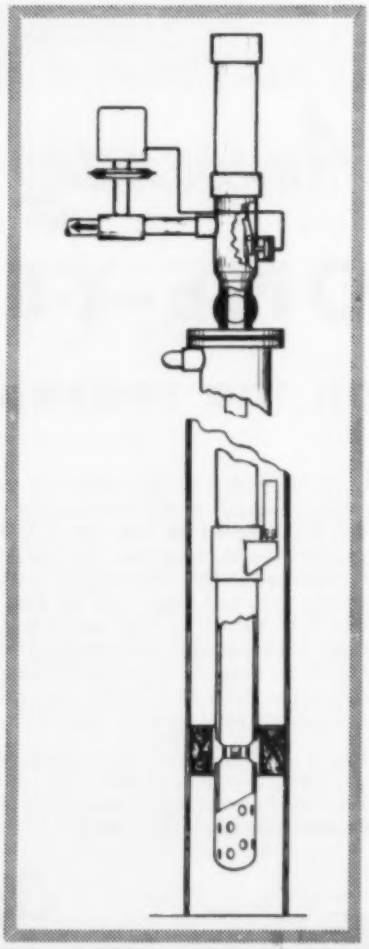
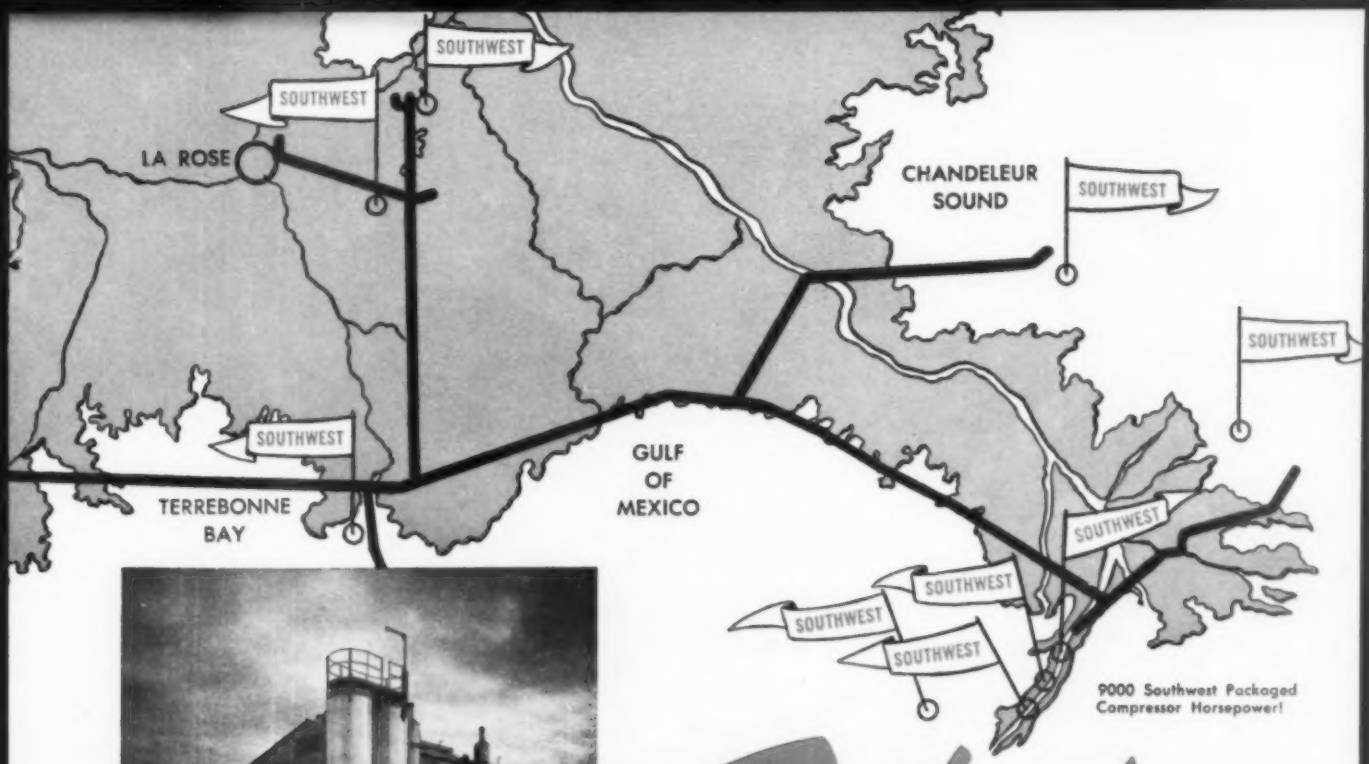


FIG. 1. **Typical free piston installation.** Every four hours, free piston is dropped from its position in lubricator to bottom of well and brings slug of fluid to surface, then goes back in lubricator.



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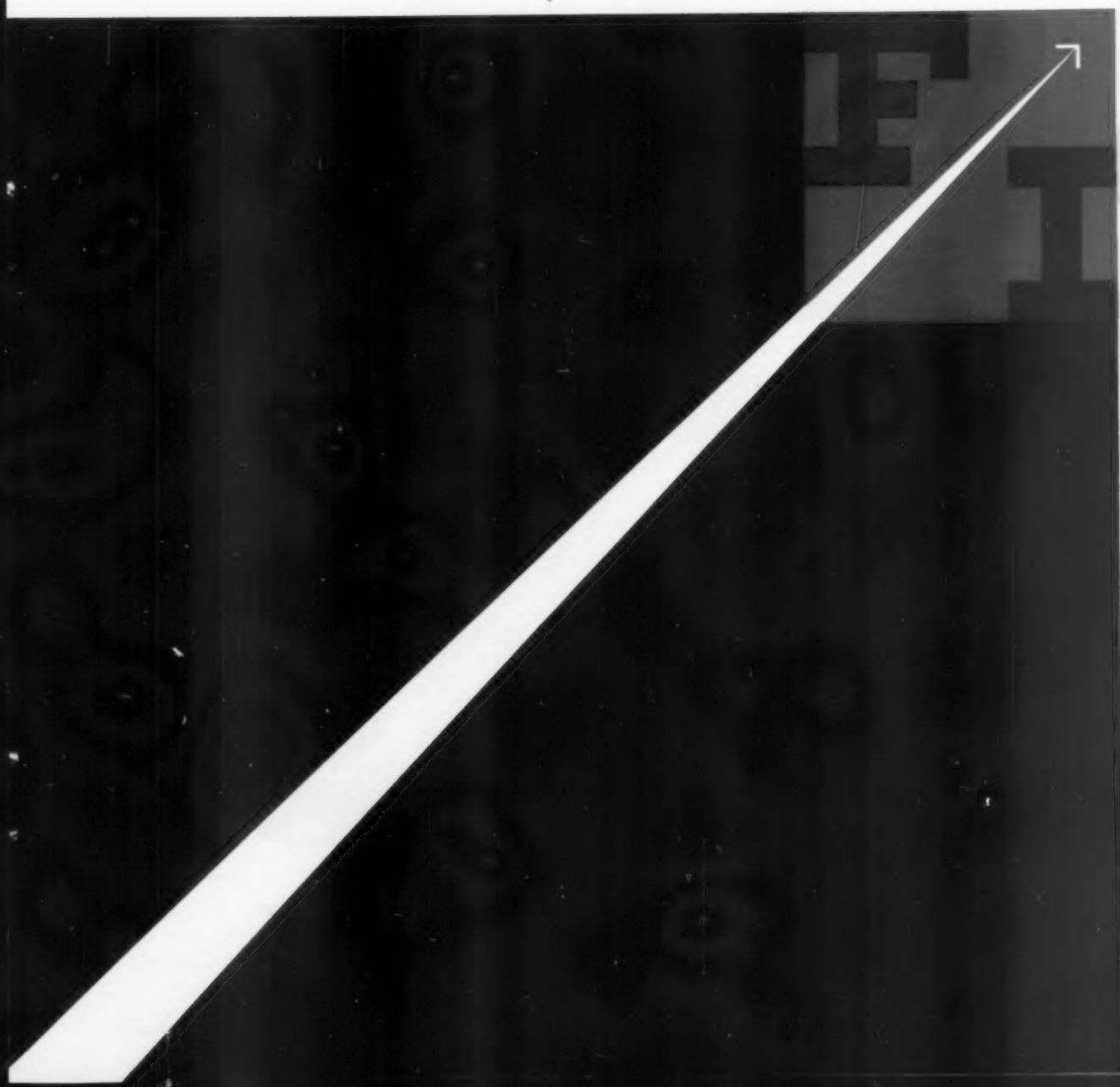

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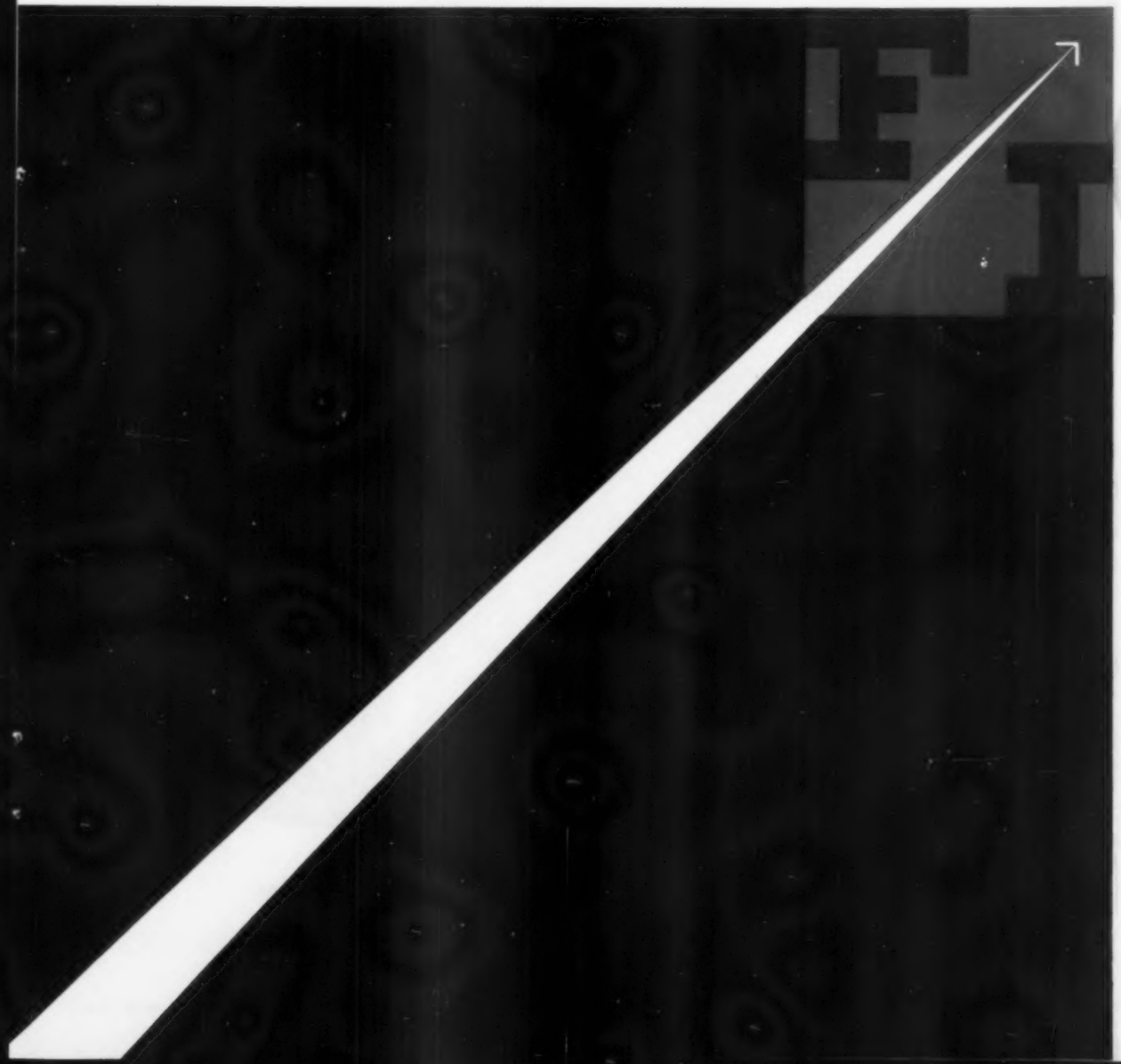

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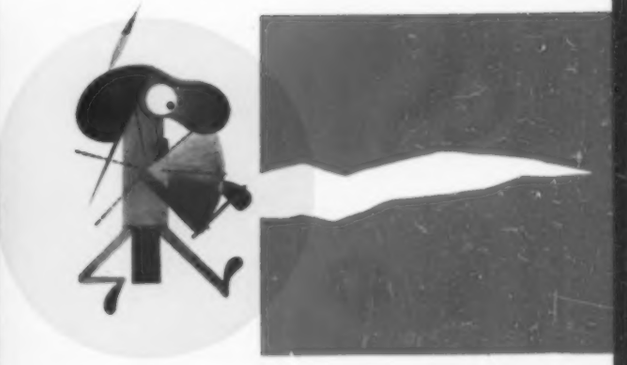

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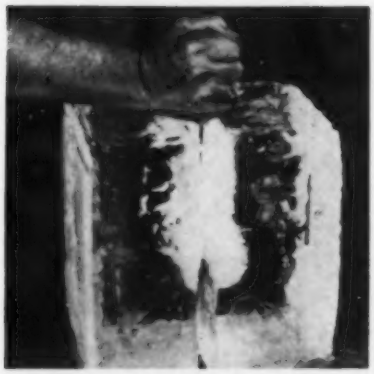

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The accurately grooved and drilled metal body of **The Martin Plunger** does not touch the barrel. Only the resilient rubber and duck rings contact the barrel. This material — with its great natural resistance to abrasion as well as its slipperyness-when-wet — has a much slower wearing action on the barrel. Most often your barrel will not need replacing. These rings have an amazing ability to take the kind of abuse that goes with oil well pumping, and this means longer runs. Plunger cost is reduced because replacing the rings costs only about one fourth as much as a new plunger, and this saving is, of course, added to the barrel saving and longer runs.

Patent No. 2,591,174

The Martin Rubber Guide Cage protects the ball from all metal contact except when it rests upon its seat. The ball is protected to such an extent that ball and seat life is usually doubled. The synthetic ball guide and stop cannot beat out because of its resilience. Its life is therefore much greater than any metal and you get this longer cage life in addition to better ball and seat life. The two guides are easily replaced when the occasion does arise.

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All regular or stroke-thru ROD PUMPS and TUBING PUMPS can be equipped with Martin Plungers. Martin Rubber Guide Cages are made in all sizes and styles. Write for our catalog No. 4; also see Composite catalog for 1956-57.

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nearly always necessary to close the well in, to enable the free piston to fall to bottom. A typical installation of this kind is shown in Fig. 1. Here we assume a typical set of conditions such as a 6000 ft well with 2-in. tubing and a packer set above the producing zone. Gas production has diminished from 500 Mcf to an average of 200 Mcf per day against a 400 psi delivery line pressure. The flow was previously switched to a blow-down line once a day for about 15 minutes to blow out some salt water and distillate to a pit. The free piston installation here includes a flow line separator, and a clock controlled flow line valve.

Once every four hours the flow line valve is automatically closed and the free piston drops from its normal place of rest in the upper lubricator to the bottom of the tubing. The time allowance is 20 minutes during which there is a rise in bottom hole pressure. On re-opening the flow line, the free piston is underneath a liquid accumulation in the tubing and starts upwards. The pressure difference necessary to lift the free piston with some 130 ft of salt water above it is obtained from two sources.

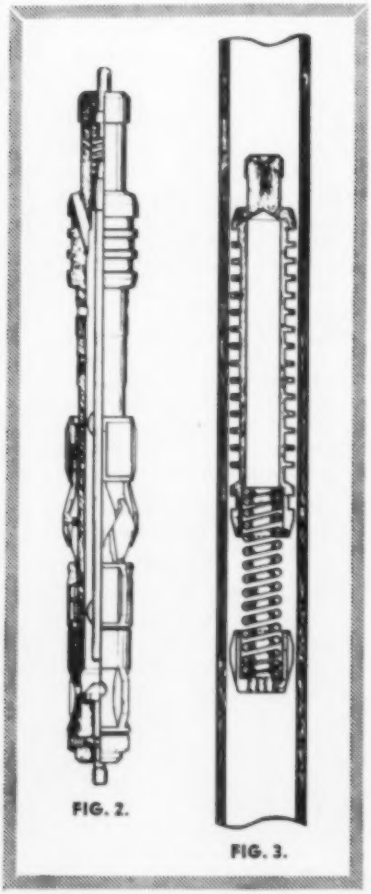


FIG. 2.

FIG. 3.

FIG. 2. **Free piston for low velocity gas wells.** FIG. 3. **Free piston for high velocity gas wells.**

First, prior to the free piston installation, the flow of 200 Mcf per day at a mean pressure of about 450 psi, would have a velocity of about 4 ft per sec and in breaking through a dispersed water column without appreciable production of the water, would have a total pressure drop comparable with that which, with a free piston, can lift all the water in the tubing at a similar velocity. The second source of additional power is, of course, the build up due to the temporary shut-in.

The slug of water is then lifted as soon as the flow line is re-opened. For any water to escape downward past the free piston during the trip upward, it would have to work down through the circumferential clearance against upwardly flowing gas at a higher pressure. For a 2-in. free piston weighing about 9½ lb pressure of the gas underneath the piston must be at least 3 psi (neglecting friction) greater than that of the fluids above it. Consequently there is no loss other than the mere wetting of the walls of the tubing. To some extent the top of one slug will pick up the leavings of the preceding slug and so on. It is certain, therefore, that all of the water picked up at bottom is brought out at the top.

At the velocity of less than 4 ft per sec, the friction loss for a water column 130 ft long is less than 5 psi so the total pressure drop across the slug and piston is of the order of 66 psi and the addition for gas flow friction and free piston friction will scarcely raise this figure to 70 psi. Weight of the gas column is about 60 psi. Thus the total difference between bottom-hole pressure and surface pressure when the slug starts upward is about 130 psi. It increases and slug velocity decreases a little before it reaches the top because of more water coming in. It drops to a minimum of about 65 psi when the piston reaches the top and rises slowly to about 120 psi again before the flow line is once again closed for the next cycle. The falling velocity goes up over 20 ft per sec but diminishes according to the dispersal of fluid in the tubing and reaches bottom falling slowly through liquid. About 20 minutes are required for a 6000 ft drop.

In wells with high flowing gas velocities, the flow may be sufficient to hold the piston in the head between cycles; where it is not, the piston is mechanically caught on its arrival, held, and released by the controller at the time the flow valve is closed.

The formation-to-well differential gradually decreases over each 4-hour period by what is virtually the static head of the liquid accumulation. The effect of a 60 psi fluctuation on the productivity will depend on many factors outside the scope of this paper, but in most cases will be negligibly small compared with the effects of 24-hour or larger liquid accumulations prior to running the piston. And, it can be reduced further.

It will also be obvious that if the cycle frequency is increased, the actual work of raising the liquid will have almost indistinguishable effects.

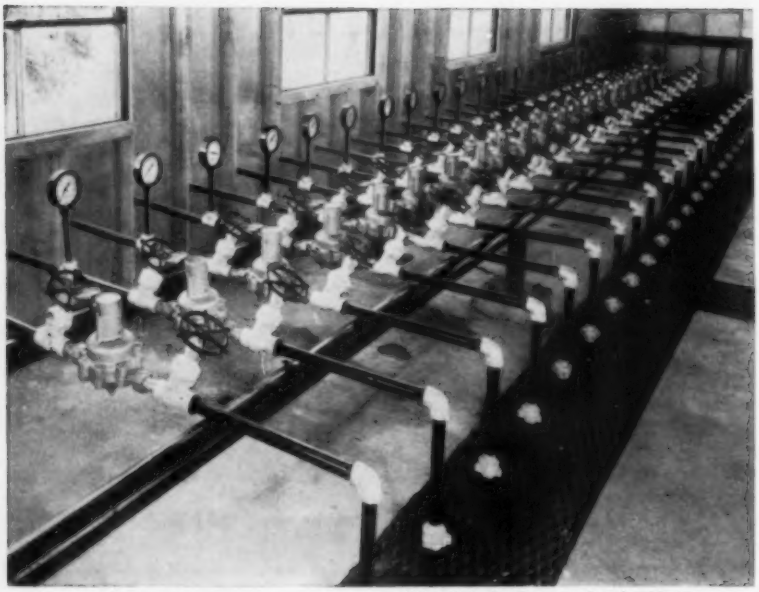
Low gas velocity wells. The type of free piston best suited to low gas velocity wells is shown in Fig. 2. It has an all-metal expanding packer to maintain an effective shut-off in spite of considerable variations in the roughness, roundness, diameter and coupling concentricity of standard run-of-the-mill tubing. It has a by-pass passage up through its interior of the largest practicable area, and a valve which is opened when the unit strikes a buffer at the top of the well and closed when it strikes a stop at the bottom.

High gas velocity wells. In wells where the gas velocity is considerably higher, a much simpler unit having no packer and no valve can be used as shown in Fig. 3. The external surface is formed with a number of circumferential recesses and the outside solid diameter is as large as practicable. At time of installation, tubing gages are run. Broaches are available for easing out tight spots in tubing if necessary. The upward gas flow against the counterflow of liquid adhering to the walls of the pipe produces turbulence and foam in each of these recesses and this contributes materially to the pressure gradient over the entire group, reducing the gas flow necessary to maintain the 3 psi pressure differential required to lift the piston. This type is relatively light in order to minimize the gas velocity for lifting it and reduce the cushioning requirements at the top. Since all of the gas which passes this type of piston is going to the sales line in any case, the quantity is unimportant.

Disadvantages of the simple unit are: (1) It cannot fall so fast, having no by-pass other than its external clearance, and so shut-in time allowances are longer, and (2) it has to be run much oftener than the free piston that can pack off, in order to lift shorter slugs to minimize the velocity reduction during lifting.

Nevertheless, it is equally true that the simple piston brings out all of the liquid with which it starts off from the bottom and the proportion of gas well de-watering jobs in which the velocity is adequate for this type is considerable.

The lowest velocity of gas flow that will bring this piston up the tubing is very roughly 9 ft per sec. It will be lower if the fluid contains oil having properties helping it to adhere to the



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The Edward valve recommended for this service was Fig. 2698 forged steel, inside screw globe valve. This valve has a precision-built interior, with no pockets to collect sediment; EValized bonnet and packing nut to prevent thread galling . . . and centerless ground stem for long packing life—and packing is easily adjusted or replaced, if ever necessary. If you've been on the lookout for an efficient, dependable valve for water flood service—and want it at moderate cost—you'd be wise to contact your nearest Edward oilfield representative . . . or your favorite oilfield supply store.

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Fig. 2698
2000 lb WOG
Globe Stop
Valve

pipe walls and make foam or emulsion in the piston grooves, and it will be higher with either all water or light distillate.

CASE HISTORIES

Turning now to typical examples, here are two Pan-American Petroleum Corporation gas wells producing from the Mesa Verde formation in the San Juan Basin:

Case No. 1. An open hole completion with 5½-in. casing at 5300 ft using 2-in. tubing and producing to a 550 psi sales line pressure. This well was blown to atmosphere at frequent intervals with an estimated gas loss of 343 Mcf per month.

After installing a free piston, production improved by 30 Mcf per day on comparable delivery periods. On two separate occasions the piston was removed leaving the automatic intermitter in service. On both occasions, the well logged off in three days yet returned each time to the higher level of gas production when the piston was replaced. Liquid produced averages 6 bbl per day.

Case No. 2. A similar well's wastage was estimated to exceed its useful production when it had previously been blown for 30 minutes every day but with the free piston was producing 2½ bbl liquid and 335 Mcf per day. When the piston was taken out to observe the effect, production fell to 156 Mcf by the third day but came back up to 350 Mcf on returning the piston to service then settled down again to 335 Mcf per day. In these cases, the elimination of blow-down wastage was of primary importance and higher allowables were obtained.

Case No. 3. The well was producing 150 Mcf per day and 5 bbl of liquid from the separator. Production jumped to 325 Mcf per day with 16 bbl of liquid when the piston was run to 4300 ft in 2-in. tubing of Murphy No. 4, Clay Basin field, Mountain Fuel Supply Company, Wyoming.

CASE HISTORY OF 18 WELLS

Reliable observations and records were made in respect of 15 installations in the Mesa Verde and three wells in Jal-Mat, New Mexico, all producing through tubing.

Liquid and gas productions were checked, the latter by individual orifice meter over the last eight days of a stabilized production period of at least three weeks. After the free piston installations, measurements were made after re-stabilization at the new production levels.

Over these 18 wells, gas production was increased from 11.655 Mcf per day to 15.879 Mcf per day, an increase

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Requiring only one pump station, at Twin Oaks, better than 83,000 barrels of gasoline or 65,000 barrels of fuel oil can be handled every day. The new 14" pipeline replaces Sun Pipe Line Company's old line . . . also constructed of National Tube pipe. It crosses three major rivers, the Schuylkill, Delaware and Raritan. These underwater portions of the line utilize the ½" wall sections, where extra stress and strain are exerted. But withstanding extra-rough conditions is "old hat" to National Seamless Pipe . . . its reputation for accomplishing difficult tasks is well established.

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of 36.2 percent. Of these, only one shows less than 10 percent improvement. Twelve range from 10 to 56 percent, four range from 100 to 203 percent and one shows an increase of 367 percent.

Omitting 4 whose fluid production had been blown to waste, 14 show a total liquid production increase from 129.2 bbl per day to 159.4 bbl per day, a 23.4 percent increase. Such an increase in liquid production obviously lowers the mean bottom-hole pressure, accounting for the increased formation-to-hole differential.

Nearer to Kingsville, Texas, is the example of some Union Producing Company wells in the Aqua Dulce field. The first two wells about 6000 ft deep were virtually shut in because of the difficulties in keeping them on production against a line pressure of 450 psi. Free pistons were installed in 1954 and in lifting all the liquid accumulations off bottom, raised the gas production to 11 MMcf per month per well.

In this area, a majority of the gas wells produce low volumes at first with a few bbl per day of distillate, fresh water and salt water. They appear to log up and die if bottom-hole pressure gets within 50 psi of the line pressure, yet six of such wells with the free piston were able to produce 200 Mcf per day and continued to produce on the average for another 2½ years.

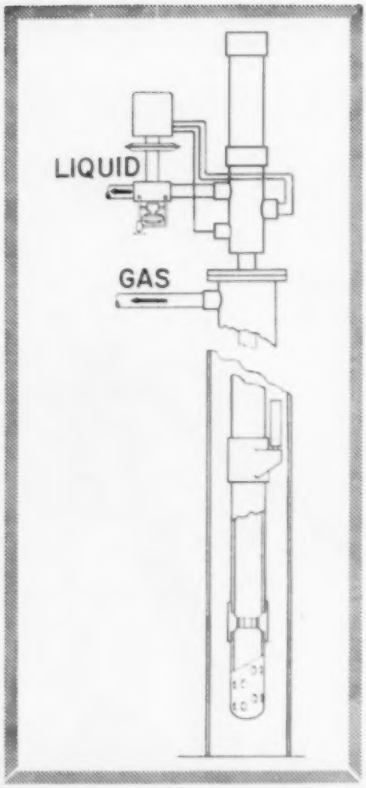

FIG. 4. **Tubing installed for the sole purpose of de-watering well.** Gas goes off the casing.

In the case of two wells for American Petrofina which fed gas to a 400 psi delivery compressor at 150 psi intake and had to be blown down by hand, net production against 150 psi diminished to an uneconomic level. With free pistons, production was raised to a combined total of 500 Mcf per day and profitable production was continued for about two years longer.

Up to this point, only wells in which, for various reasons, the gas and liquids are all brought out through the tubing string have been discussed. In many of these wells, paraffin had been deposited in the tubing string, thus restricting the flow of gas. Extensive work was sometimes necessary to cut paraffin and make way for the free piston. In all cases, the free piston eliminated the paraffin problem thereafter.

Turning now to a much more satisfactory de-watering method, Fig. 4 and 5 show a similar installation but here the gas is taken off the casing head and the tubing is relegated to the sole duty of lifting the liquid. The tubing flow line in this case usually goes to a low-pressure separator, unless the liquids present are all valueless when it may lead to a pit. The separator, if desired, can be back-pressured up to a

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value lower than the casing head pressure by about 125 percent of the static head of the slug being lifted.

It will be apparent that with a casing annulus area so much larger than that of the tubing, the gas velocity upward will be so much less that there will be very little fluid lifted by the gas stream. In effect, a very long separator is formed. There may be downward trickles of liquid on the surfaces of tubing and casing, especially toward the bottom, but in all probability the gas at the casing head will be so clean and dry that dehydrators quite often will be unnecessary.

The pressure drop over the gas column in the casing is obviously reduced, first by the absence of dispersed fluids, and second by the low friction loss at the lower velocity. Accordingly, the total drop will be only a few psi over the static gas column weight of about 65 psi at most, and the bottom-hole pressure is then continuously maintained very close to its theoretical minimum for the given delivery line pressure. The formation-to-hole differential and gas production therefore are closely approaching the optimum.

The controller motor valve in this case is provided with a small by-pass. This takes a small flow of gas from the tubing head continuously over the whole period of time between successive cycles and is adjusted to reduce the tubing head pressure by an amount equal to the static head of the slug to be lifted. This makes sure that the whole liquid accumulation for that time interval is in the tubing string before the main valve opens, and none in the casing annulus.

By flowing against a much lower back pressure, larger slugs at lower frequencies may be adopted for most gas wells, but by the same token, larger quantities of liquid can be handled.

Velocity of the free piston and its slug are now of lesser importance and a lower velocity can be adopted. The efficiency of the lift can then be maintained at 70 to 80 percent of the theoretical maximum represented by the production of a slug whose static head equals the pressure difference available to lift it. The type of free piston used will nearly always be one having a closely fitting pack-off and capable of operating in extremely low gas velocities.

Operators in the New Mexico area are now completing their newly-drilled gas wells for casing production with free piston installations. Two-inch tubing is run solely for de-watering and it has no packer. The next step in exploiting the potential benefit of the free piston in gas wells will be the adoption of 1½ and 1¼-in. tubing strings. This move is already being anticipated.

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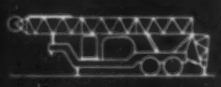

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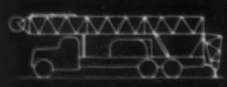

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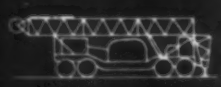

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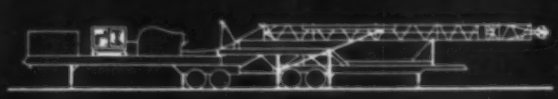

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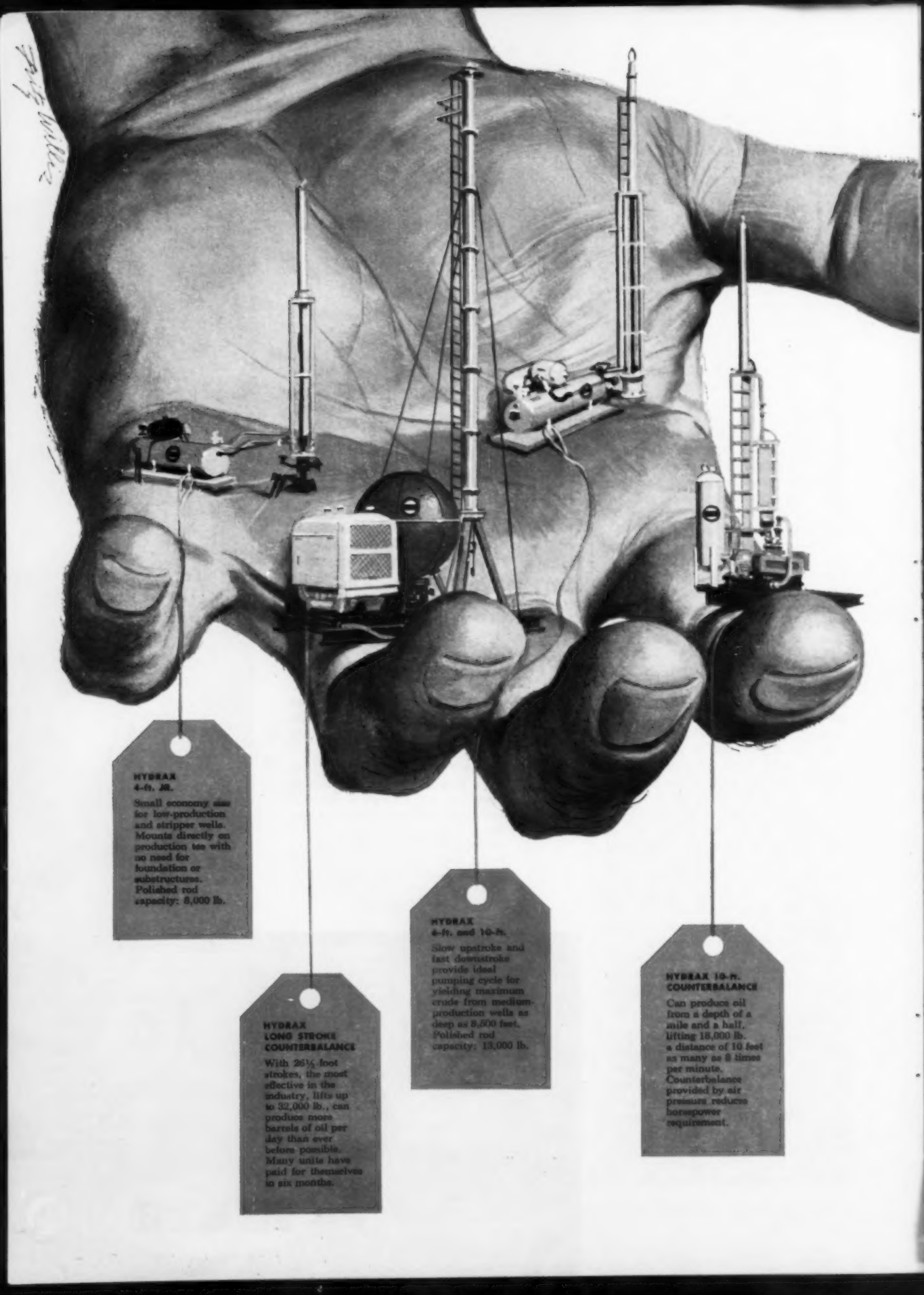
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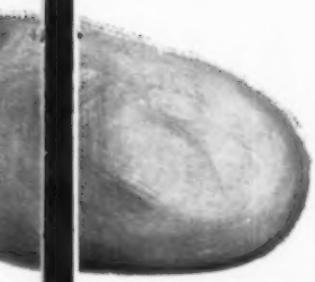

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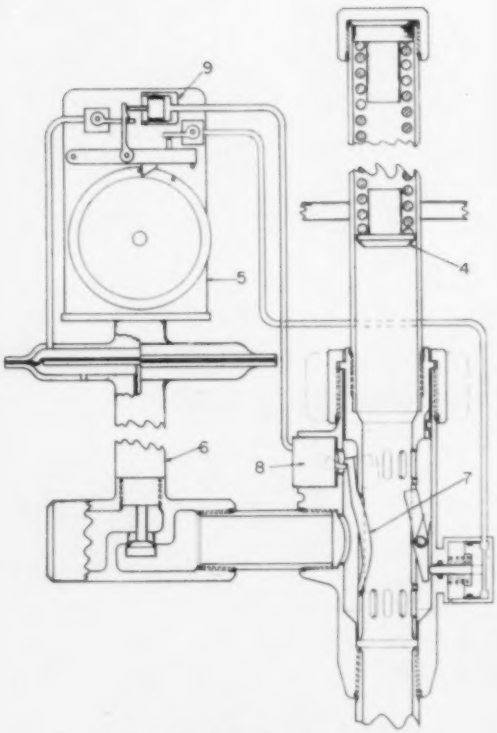

FIG. 5. **Timing mechanism and lubricator trap for free piston.**

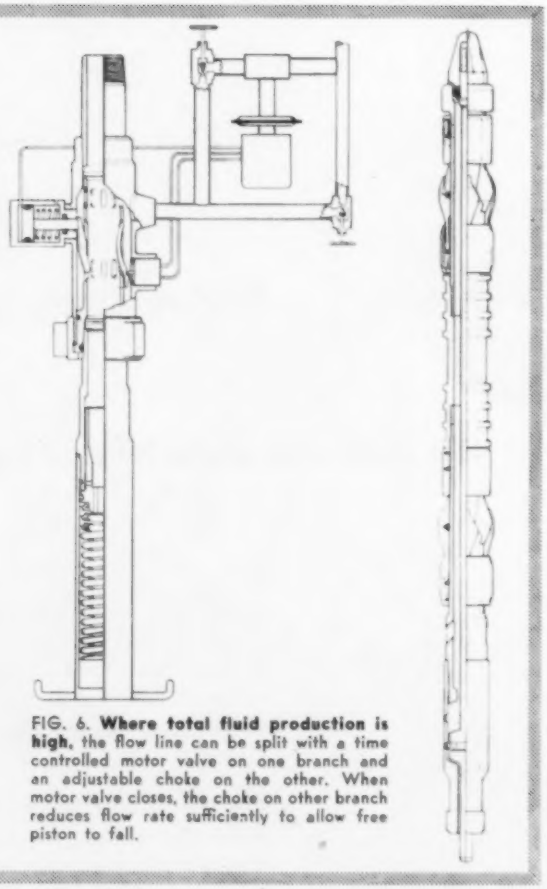

FIG. 6. **Where total fluid production is high,** the flow line can be split with a time controlled motor valve on one branch and an adjustable choke on the other. When motor valve closes, the choke on other branch reduces flow rate sufficiently to allow free piston to fall.

With a casing/tubing area ratio on the order of 10 to 1 and a free piston with a good pack-off and allowing traveling velocity, the casinghead gas flow is diminished very little during a liquid lifting cycle and for all practical purposes it will be a straight line graph.

Casing versus tubing. Summarizing the advantages of casing gas production over tubing gas production:

1. A lower mean bottom-hole pressure can be maintained with no liquid accumulation in the casing but all in the tubing. This permits higher gas production rates approaching the theoretical maximum possible.
2. Much larger quantities of liquid can be handled.
3. Gas produced from the casing head will have moved up through a long "separator" at low velocity and is cleaner and drier.
4. Gas flow is not interrupted by liquid lifting cycles and flow rate fluctuations are virtually negligible.
5. Liquid lifting efficiency is raised to a very high level minimizing the quantity of gas released to low pressure for lifting liquid.
6. Tubing size no longer has to be larger than 2-in. for large gas wells and at an early date 1½ and 1¼-in. free pistons will be available.

TABLE I. **Gas Production Case Histories,** before and after de-watering with the free piston installation. First 15 wells are in the Mesa Verde field, last 3 in the Jal-Mat field, both in New Mexico. Case 19 is also in the Mesa Verde field.

	Gas - Mcf/Day			Liquids - Bbl/Day		
	Before	After	%	Before	After	%
Production Through Tubing						
1 Barrett #1	907	998	10	8.9	8.9	0.0
2 Barrett #2	1061	1149	8.3	8.1	9.8	21.0
3 Barrett #3	616	735	19.3	6.5	7.0	7.7
4 Barrett #4	428	490	14.5	3.5	4.2	20.0
5 S. Juan 32-9 #1	577	705	22.2	15.3	16.6	8.5
6 S. Juan 32-9 #4	869	1165	34.1	15.7	21.8	38.9
7 S. Juan 32-9 #5	841	946	12.5	14.1	18.8	33.3
8 S. Juan 32-9 #16	273	566	107.3	3.3	5.7	72.7
10 S. Juan 32-9 #23	573	661	15.4	1.4	2.0	42.0
11 Scott #4	572	650	13.6	1.4	2.4	71.4
12 Scott #5	1018	1306	28.3	15.0	16.0	6.7
13 Marcotte #1	1653	2021	22.3	30.4	39.2	28.9
14 Riddle #2-C	1000	1145	14.5	5.6	7.0	25.0
15 Riddle #1-E	238	722	203.4	—	—	Av 23.4%
16 Jenkins #1	100	467	367.0	—	20.0	—
17 Jenkins #2	250	500	100.0	—	15.0	—
18 Bates #2	300	467	56.0	—	5.0	—
			Av 36.2%			
Production Through Casing						
19 Atlantic State #6	8	72	800.0	2.8	23.0	721.0

In addition to the 18 wells previously mentioned, records of reliable accuracy are available in respect of only one well which had originally been equipped for tubing gas flow and was converted to casing flow. Two others gave comparable results but as data were less reliable, they are not used here.

In Atlantic State No. 6 well, producing from the Mesa Verde, the free piston improved liquid production from 1.1 to 2.5 bbl per day, an increase of 127 percent and improved gas production from 8 Mcf to 72 Mcf per day, an increase of 800 percent.

Costs. Installation costs may vary

Here is versatility and high production all in one low cost team . . . the Brewster N-45 and the Lee C. Moore Dual trailer 100 mast. This self-moving drilling combination is a winning team for many contractors . . . big enough to make hole fast, small enough to move in on shallow work or to drill to 6,500 foot . . . profitably.

Economical in first cost, the N-45 has field proved features that have given Brewster rigs their reputation for low operating costs.

Available in torque converter and mechanical designs, the N-45 can be ordered with the compound and power arrangement best suited to your individual needs. These options include: twin engines with individual torque converters, twin engines with midship torque converter, dual engines with chain compound and pump drive and single heavy duty engine without compound. All models have full air controls, enclosed oilbath chain drives, chain transmissions, big brakes and extra large drums.

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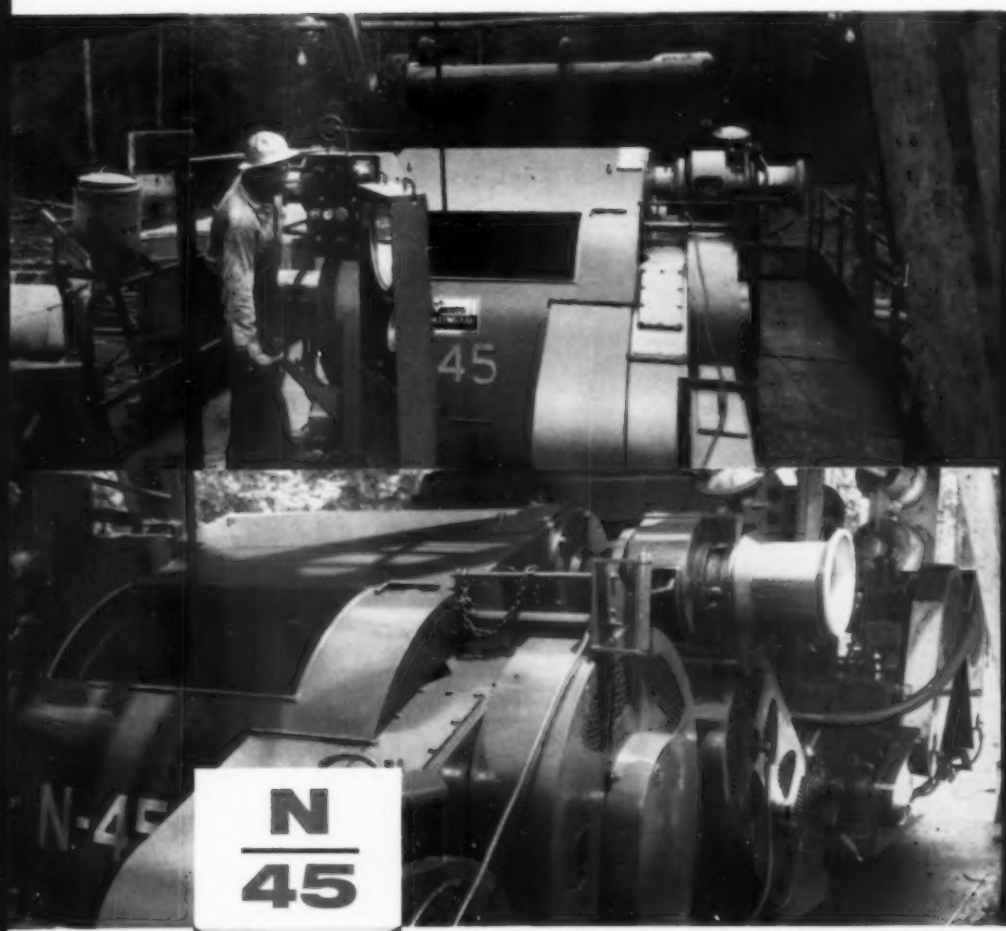

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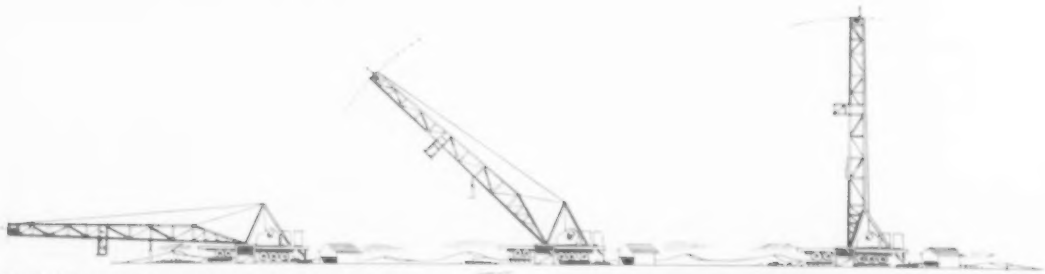
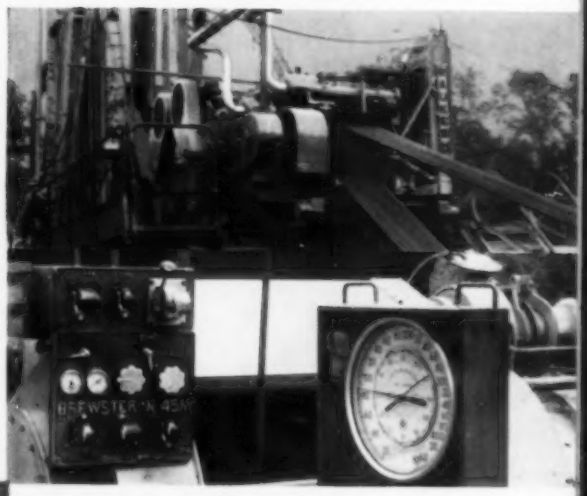


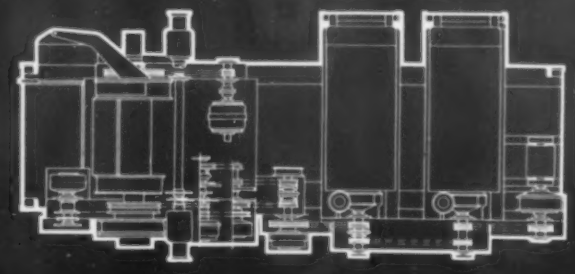
Single trailer mounted masts combined with the Brewster N-45 drawworks give maximum mobility and efficiency.

N 45

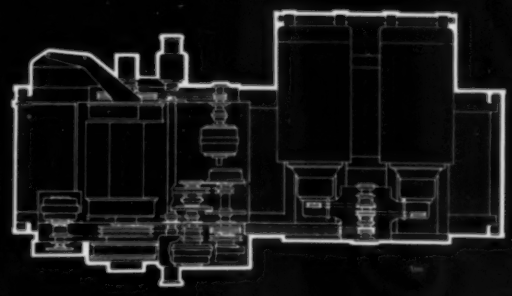
RUGGED COMPOUND

The N-45-M has a heavy duty chain compound with take-off to a pedestal mounted mud pump drive. The compound and engine are coupled by Fawick air clutches. A positive clutch on the inboard engine compound shaft permits the pump drive to be powered by one or both engines. A combination of oil bath and oil pressure lubrication is provided to chains and shaft bearings.





N-45-M—MECHANICAL DRIVE



N-45—TORQUE CONVERTER DRIVE

FULL AIR CONTROLS

Fingertip air controls on the N-45 give the driller instant positive command of the drawworks, compound, engines and pump drive. Hi and low drum speeds are obtained by a single dual position valve. The driller can shift from low to high without stopping the load.

VERSATILITY

The N-45 is designed in two basic models, one for use with torque converter drive and the other for straight mechanical drive arrangements. Both have chain transmissions with two forward speeds and a gear reverse furnished in torque converter models and four forward speeds and gear reverse in mechanical models. A wide choice of engine combinations and compound arrangements provide complete flexibility of make-up permitting you to match the rig with other equipment or to design it for a particular type drilling operation.

SPECIFICATIONS

Recommended Horsepower	450
Drum Spool diameter and length	18" x 40"
Net Braking Surface (Lining) Square Inches	1,728
Drum Brakes	8" x 40"
Hoisting Speeds	
Torque Converter Models – 2 Fwd., 1 Rev.	
Mechanical Drive Models – 4 Fwd., 2 Rev.	

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Shreveport, Louisiana

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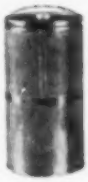

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from about $900 to $1600, depending on the size of tubing and type of controls and surface fittings needed.

In a considerable number of successful de-watering installations in the Longwood, Ivan, Rodessa, and Caspiana fields of North Louisiana and in the Carthage field of East Texas, a considerable part of the fluid production increase obtained is marketable condensate which in many instances had previously been blown away. This revenue has materially contributed toward keeping down the average time for payout.

Payout generally averages about four months with variations down to less than one month and seldom exceeding nine months.

Splitting flow line. In wells where the total fluid productions are considerably more than those we discussed and where flowing conditions can only be maintained by repeated purgings, it is sometimes undesirable to shut the well in at the cycle frequency necessary to lift all the liquid.

In these installations it has been found very satisfactory to split the flow line, installing a time controlled motor valve on one of the branches as shown in Fig. 6. An adjustable choke on the other branch is then set to reduce the flow rate of the well sufficiently to allow the free piston to fall when the motor valve closes its branch.

The lubricator shown here is that of the previous Fig. 5 where the free piston is automatically retained in the head on its arrival and released only when the motor valve closes. For this type of work, however, the mechanism for closing the motor valve on arrival of the free piston would be used only where it is desirable to cycle at maximum frequency. Where the cycle frequency desired is other than the maximum possible, the pilot valve with associated mechanism is omitted and the controller clock is in control of the frequency.

The free piston illustrated here is an alternative to that shown in Fig. 2 and is fitted with two packer assemblies placed some 10 in. apart. The need for this occurs in many wells where the master valve or another of the Christmas tree fittings is oversize. In many such installations, the upward velocity may be insufficient to carry the free piston over the gap, but this type can re-establish a seal above an oversize gap before the lower packer loses it.

Acknowledgment

This article is based on a talk given by the author at the Southern Gas Association Short Course in Gas Technology held May 29-31 at Texas College of Arts and Industries, Kingsville, Texas.

★ ★ ★

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Gulf's Houston Production Division Announces Reorganization Structure

EXTENSIVE changes in the Houston Production Division of Gulf Oil Corporation's organizational structure, announced recently by Division Manager S. G. Sanderson, are now effective.

Principal among the new positions are those of the four district managers who will be in charge of the newly-designated Houston, New Orleans, Jackson and Shreveport districts. These new organizational segments will link together under a single management the former exploration and production zones.

Heading the division organization and responsible for its operation will be Divison Manager Sanderson.

At this level, Division Production Coordinator L. H. Moore, Division Exploration Coordinator G. O. Relf, Jr., and Division Comptroller and Services Coordinator F. C. Anderson, and Sanderson, comprise the division operating committee. This group will be responsible for recommendations covering policies and plans pertinent to production, exploration and services activities, respectively. In addition to these staff functions, Anderson will continue to supervise accounting activities of the division. The three coordinators will report to the division manager.

District managers will be responsible for company activities within their respective districts and will report directly to division manager Sanderson. The four new district managers and their respective districts are: W. A. Shellshear, Houston; R. A. Payne, New Orleans; W. W. Ramseur, Jackson, and B. W. Haywood, Shreveport.

District production managers and district exploration managers, formerly designated zone production superintendents and zone exploration superintendents, will continue to be responsible for production and exploration activities. District services managers will supervise service activities within their respective districts, comprised of purchasing, warehousing, transportation, civil engineering, accident prevention and clerical duties. The district exploration, production and services managers will report to the district manager. With the district managers as chairman, these four will compose the district operating committee.

The new district exploration managers and their respective districts are: T. R. Deen, Houston; H. D. Ritter, New Orleans; J. L. Herndon, Jackson, and R. C. Howard, Shreveport. J. D. Nunnally is offshore district exploration manager.

District production managers and their areas are: J. P. Weichert, Houston; W. B. Hopkins, New Orleans; M. C. Coleman, Jackson, and F. J. Mikeska, Shreveport. Offshore district production manager is O. W. Crisman.

District services managers are N. B. Martin, Houston; J. A. Austin, New Orleans; D. R. Carmichael, Jackson, and J. J. Mathis, Shreveport.

No district manager has been named for the offshore district's operations. Nunnally and Crisman report directly to the division manager.

All changes were made in an effort to heighten the efficiency of division operations through a decentralization of managerial authority and responsibility, Gulf reports. ★ ★ ★

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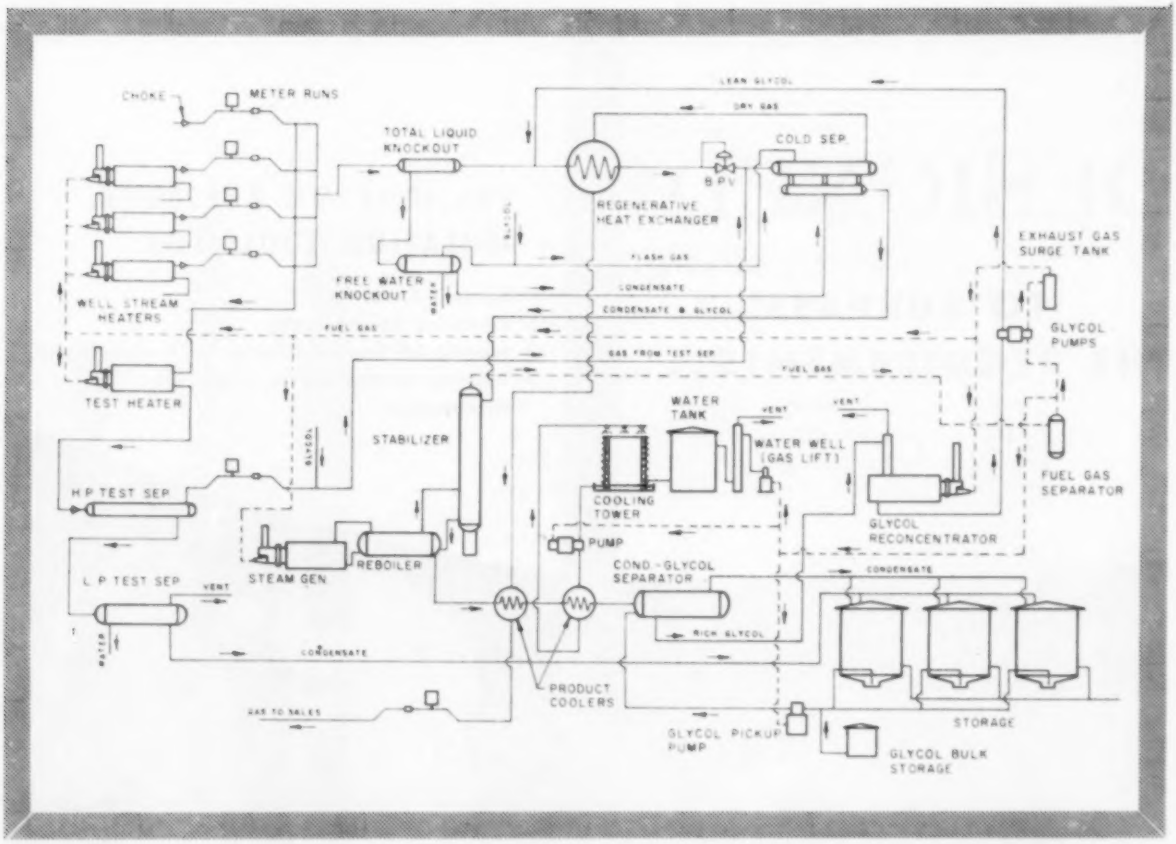

FIG. 1. Flow diagram of low temperature separation-stabilizer plant. Many unique innovations were included in the design for processing flexibility and maximum efficiency throughout operating life.

Efficient Operation Highlights . . .

Hallsville Gas Handling System

C. K. Gravis | R. E. Fields

Sub-hydrate flowing temperatures, high liquid volumes, test requirements and swampy terrain are met with unique central LTS installation

LOW temperature separation and stabilization at a central location was chosen as the best way to produce four gas-condensate wells on adjacent leases in the South Hallsville field. Cost estimates and economic calculations guided the design and sizing for optimum condensate recovery. Field life and reserve estimates were important considerations. These leases are in the Sabine River flood land, inaccessible after heavy rains. Sub-hydrate flowing temperatures, high liquid volumes, testing requirements, and swampy terrain were all special design problems.

Normal stage separation, dehydration, and full well stream sales were also evaluated as producing methods. Any plan for individual lease operation requiring daily attention was unattractive, for the low elevations would have called for costly all-weather lease road construction.

Preliminary planning indicated a high-pressure gathering system and a central low temperature separation-stabilization facility would be most profitable. It would also assure dehydrated gas for sale to a gas transmission company. This plan proved feasible as there was one high plot of ground conveniently located. The plant was installed and placed in operation in August 1956, after planned training of operators and supervisors.

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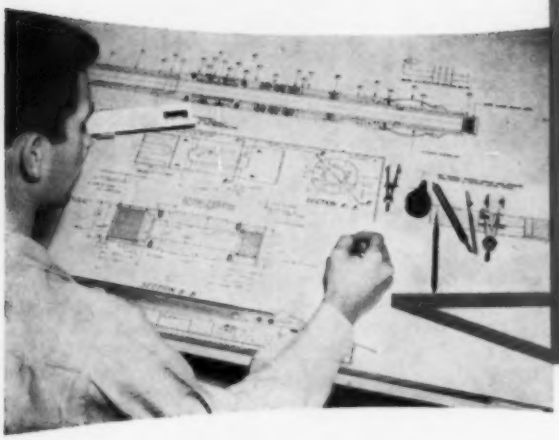

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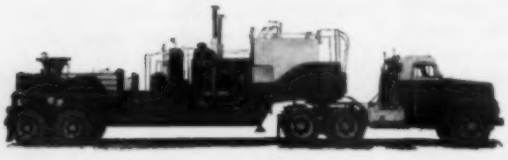

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HALLIBURTON "DM"-"DC" SQUEEZE PACKERS AND BRIDGE PLUGS (Drillable Magnesium, Drillable Cast Iron)

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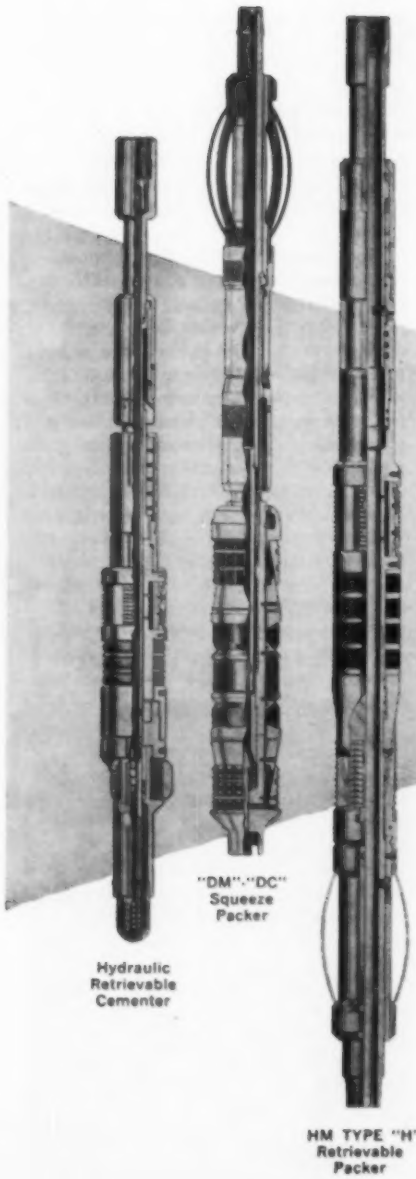

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HALLIBURTON DOC (Diesel Oil Cement)

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Central LTS Plant

The Atlantic Refining Company and Trahan Drilling Company as operators completed productive gas-condensate wells in the Pettit formation on adjacent leases. These leases are in the South Hallsville field of the Pettit-Crane trend. One well is jointly owned by both companies.

There were two market possibilities in this field, and the first big question was how to sell the gas: (1) By full well stream sale to a gasoline plant, or (2) dehydrated gas sale into a gas transmission line. Full well stream sale sounded attractive off-hand because of the low initial investment and because of all-weather inaccessibility for well or lease equipment operation. The end result has shown that it paid to investigate all the possibilities.

It was necessary to consider much more than initial conditions, both for design and for economics. Reserves, tubing pressure decline, retro-grade condensation, optimum operating temperatures, etc. were all important factors.

Economic study indicated that low temperature separation (LTS) and sale of dehydrated gas would be most profitable in this case. Calculations showed that a stabilizer would also pay out and contribute considerable additional profit. After all economic possibilities had been considered, it was agreed to install jointly owned gas handling facilities.

Costs of normal stage separation and other types of dehydration were also considered. As in many cases, however, LTS equipment alone could be installed for little more than normal temperature separation and a dehydrator. Stabilization, an additional cost, was justified on the basis of additional recovery attributable to it.

Initial condensate recovery with LTS-stabilization was calculated at over 600 bbl of oil per day of 12 RVP product, while stage separation was tested to give only 480 bbl per day. Stabilization would account for about half of the difference. With the LTS process, of course, dehydration is automatically obtained by the use of hygroscopic diethylene glycol.

Tubing pressure of about 2300 psi at 10 MMcf per day flowing rate was expected. The sales contract specified not greater than seven pounds of water per MMcf of gas. The maximum delivery pressure was to be 1000 psi at the transmission company's main line. Thus, design conditions were established.

Gathering System

Individual flow lines were installed with working pressure great enough to handle 2800 psi shut-in well pressures. This allows flow to the plant at full wellhead flowing pressure for best low temperature separation efficiency. It also accommodated an individual well test system, and individual flow rate control from the central plant.

Hydrate formation in the flow lines would be a problem due to the difficult terrain features and the low flowing temperatures. Hydrates were expected to form at about 75 F at this pressure. On test, the wells flowed close to this temperature. Several heaters would have been required ordinarily to maintain flow above hydrate temperature. Heater installations would be expensive if installed above the flood water level, and in case of high water they would be inaccessible part of the time unless an elaborate road extension was built. Since the wells would flow with an oil/gas ratio of about 80 bbl per MMcf, Atlantic decided to try flowing without the use of flow line heaters and rely on the liquid to carry any hydrates that would form. The lines were laid with a minimum of sharp turns or bends to prevent hydrate clogging or pile-up. Flowing rates were eventually lower than anticipated. As a result, hydrates did not carry through as well and heaters were added to the longer flow lines.

Indirect heaters are installed on each flow line as they enter the central plant. These heaters are used to melt the hydrates and permit enough choking to adjust for proper flow rate from each well.

Process Flow

After flow through the heaters, each full well stream is metered and then the flow is manifolded together for low temperature (LTS) processing. Fig. 1 is a simplified flow diagram of this process.

The composite full well stream enters a total liquid knockout in which all liquids are removed and passed to a water knockout. The water knockout removes free water and discharges it to a pit. Condensate is routed from the free water knockout to the cold separator.

Gas leaving the total liquid knockout passes through the regenerative heat exchanger, a back pressure regulator, a hydrate catcher, and into the cold separator. The back-pressure regulator holds a back pressure on the well streams which is now about 1900 psi. The pressure is reduced here to transmission line pressure which is about 800 psi. Reduction in pressure causes a reduction in temperature as the stream enters the cold separator. The low temperature in this separator causes optimum condensate recovery and dehydration of the gas simultaneously. Diethylene glycol is injected into the gas stream just prior to entering the regenerative heat exchanger to prevent hydrates from forming as the gas is cooled to sub-hydrate temperatures.

After the gas has been separated from the condensate-glycol mixture, it leaves the cold separator, passes through the regenerative heat exchanger to cool the incoming well stream. Condensate leaving the cold separator is processed through the stabilizer and then is cooled with both gas and water cooling. From the product coolers, the glycol-condensate mixture is routed to the glycol-condensate separator. Glycol is removed in this separator before condensate flows to storage. The water rich glycol recovered is routed to the glycol reconcentrator, the lean glycol being pumped back into the incoming well stream.

Fuel System

The liquid in the stabilizer flashes considerable overhead gas. This excess gas, consisting mostly of propane and butane, is used as plant fuel for best conservation. With the stabilizer operating at about 60 psig there is adequate pressure to run the gas operated glycol pumps. After expansion in the glycol pumps the gas is exhausted into a low-pressure surge tank. From there, it serves as fuel for the steam generator, heaters, and reboiler. In case the

The Authors

C. K. Gravis

R. E. Fields

C. K. Gravis has been associated with Atlantic Refining Company since his graduation from Southern Methodist University in 1951. He holds a degree in mechanical engineering. His duties with Atlantic have been largely concentrated on the application of lease surface production equipment. He has specialized in the equipment and methods for gas and gas-condensate handling, separation, and processing.

R. E. Fields is a senior production engineer in the Dallas Production Engineering Group of The Atlantic Refining Company. He graduated from Missouri School of Mines in 1941 with a degree in mechanical engineering. He joined Atlantic in 1945 after service in World War II. He worked as district engineer in Atlantic's Denver City District in West Texas before assignment in the Dallas Staff Group.

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PETROLEUM ENGINEERING NEWS

LATEST PROPERTY AND APPLICATION DATA ON TEFLON® tetrafluoroethylene resins

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Seals, gaskets and packings of Du Pont TEFLON tetrafluoroethylene resins give outstanding service in pipelines and process equipment. Sealing devices of TEFLON resins have amazing durability, even under the most adverse conditions.

In the case of the gate valve pictured, TEFLON resins were selected after consideration of several seal materials. A TEFLON resin is specified because of chemical inertness, lack of tendency to swell or crack, its toughness and durability. TEFLON resins provide a tight, leakproof seating for the gate. Valve operation is more efficient, and maintenance costs are sharply reduced.

Most of the mechanical strength properties of molded TEFLON 1 or TEFLON 5 are comparable with those of the best grades of rubber-bonded compressed asbestos. In addition, TEFLON resins have a naturally slippery surface, which facilitates operation of mechanical parts. Designers take advantage of this property to make "self-lubricating" bearings and bushings. TEFLON resins are tough and strong, and are used to make structural elements. Rated for use up to 500°F., TEFLON tetrafluoroethylene resins show no brittleness at temperatures as low as that of liquid helium.

Du Pont TEFLON resins are unaffected by petroleum distillation products, catalysts and reagents. They are completely inert to acids, aliphatics, aromatics, chlorinated hydrocarbons—virtually all chemicals and solvents in commercial use. The few exceptions to this include attack by the alkali metals under certain conditions. At high temperatures and pressures, halogens and certain halogenated chemicals and solvents may also affect TEFLON resins.

The next time design of a juncture or closure presents problems of leakage and excessive maintenance, look into the possibility of using Du Pont TEFLON tetrafluoroethylene resins. Additional material on this subject is available. Just mail the coupon.

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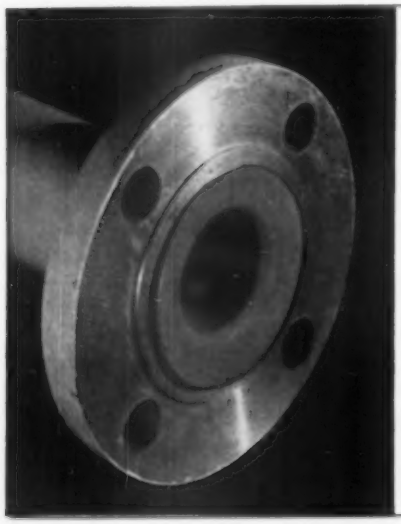

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stabilizer would fail to furnish sufficient pump fuel at any time, makeup gas is supplied automatically from high-pressure gas going to sale. A pressure reducing regulator opens below 55 psi to furnish this makeup.

Test System and Stabilizer By-Pass

Whenever several wells produce at full well pressure into central processing facilities, there must be a means for individual well testing. Regular testing is necessary to evaluate individual well performance as well as to prorate credit for condensate to each lease. Feasible methods for doing this are (1) stage separation testing at the central unit, (2) split stream sampling, or (3) separation, metering, and recombining at wellhead pressures for each well. The first of these three methods was chosen as economical and most convenient for South Hallsville. Split stream sampling is not considered accurate here because of the high liquid content. Metering and recombining of individual well streams involves costly equipment.

The test unit consists of an indirect heater, choke, and two stage separators. Oil-gas ratio tests are conducted on any well without shutting any well in or interfering with the plant operation. The inlet manifold enables flow to be switched through the test system. The low-pressure test separator removes water from the condensate so that formation water will not contaminate the glycol which accumulates in the stock tanks. Condensate flows to stock through a separate test line.

Gas from the high-pressure test separator is metered and then routed through the main cold separator. Since this gas can be cooled with the main stream, losses due to testing are minimized.

The test unit is also arranged to serve as a stabilizer by-pass. By-passing may be desirable for stabilizer inspection or maintenance. In this case condensate from the main high-pressure separator is routed through the test heater to raise the condensate temperature to 90 F for storage. This is preferable to dumping sub-zero liquid to stock. Flash gas due to increased temperature and decreased pressure is removed in the low-pressure test separator. Glycol is removed from the condensate in the condensate-glycol separator enroute to storage. When the test low-pressure separator is used in the stabilizer by-pass process, the water dump valve is placed out of operation to prevent glycol loss to the water dump pit.

Heat Exchanger

The heat exchanger for this unit was designed using the sizing method we have found to be most satisfactory. This method consists of finding several heat transfer surface areas for different approach temperatures. The approach temperature is the difference between the well stream inlet temperature and the sales gas outlet temperature of a heat exchanger. To do this it was necessary to find the lowest flowing pressure upstream of the choke which would give a separator temperature of minus 20 F at the several approaches. The heat exchanger costs for the various surface areas are then compared with the recoveries they will give through the flowing life of the wells. The recoveries are obtained from predictions of recovery (bbl per MMscf) vs separator temperature and flowing pressure vs lift. (See Fig. 2.)

This is the means for selection of the optimum design. In other words, a heat exchanger is selected that will give the most recovery for the cost. This heat exchanger will maintain the lowest operating separator temperature that is economical through the flowing life.

In this instance, heat exchanger costs were figured for approaches of 15 F, 10 F, and 5 F. Each exchanger was justified over the smaller, less costly one on a payout basis. The differential costs between heat exchanger sizes were small in this case and the recovery gains good, so the short payouts showed

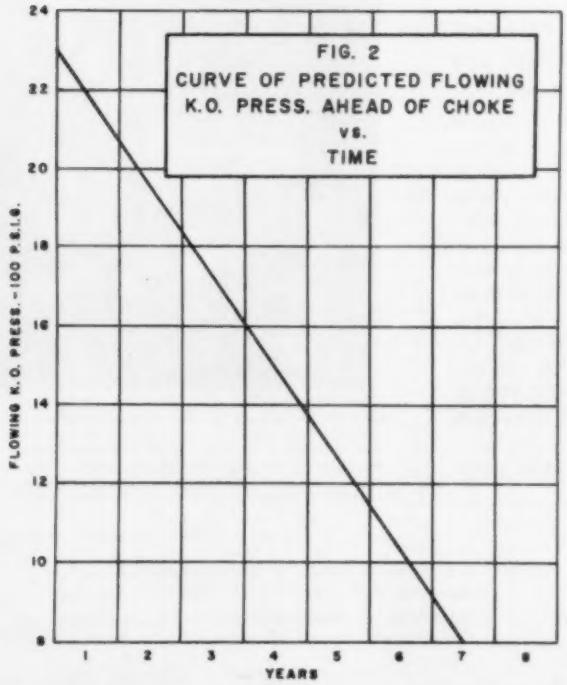


FIG. 2. Anticipated decline of water knockout pressures to sales gas line pressure figured heavily in plant design and economics.

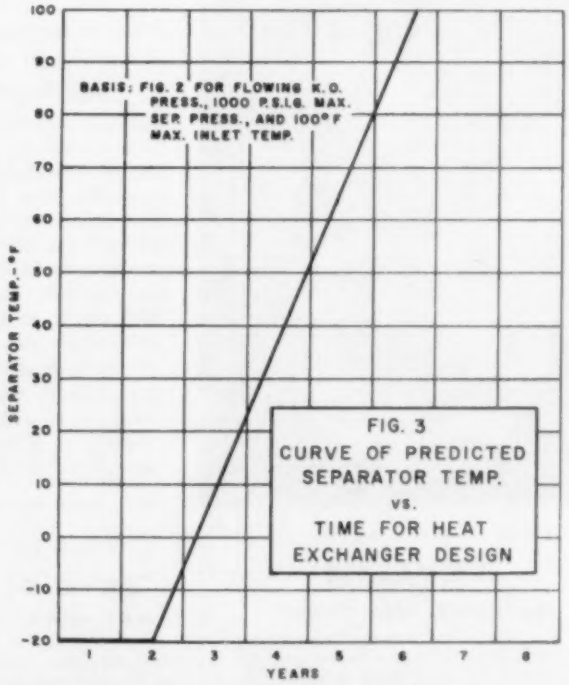
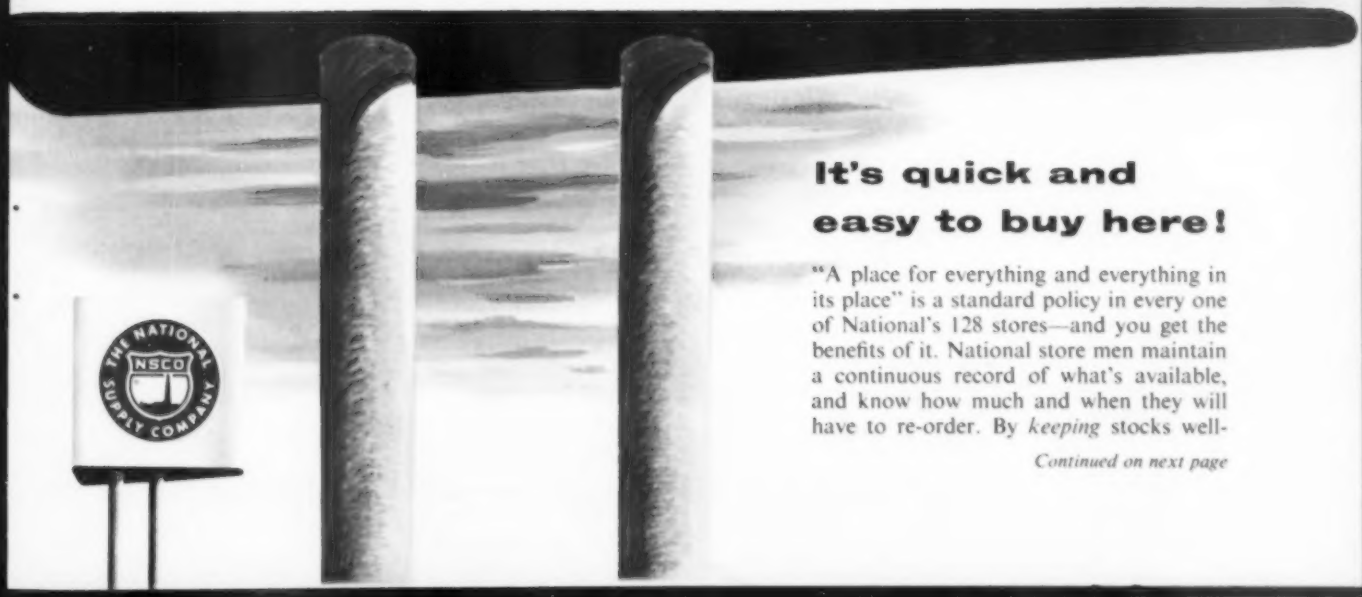


FIG. 3. Economic studies showed that heat exchangers based on a 5 F approach temperature would be preferable. Above is an estimate of the separator temperatures during the operating life of the unit.



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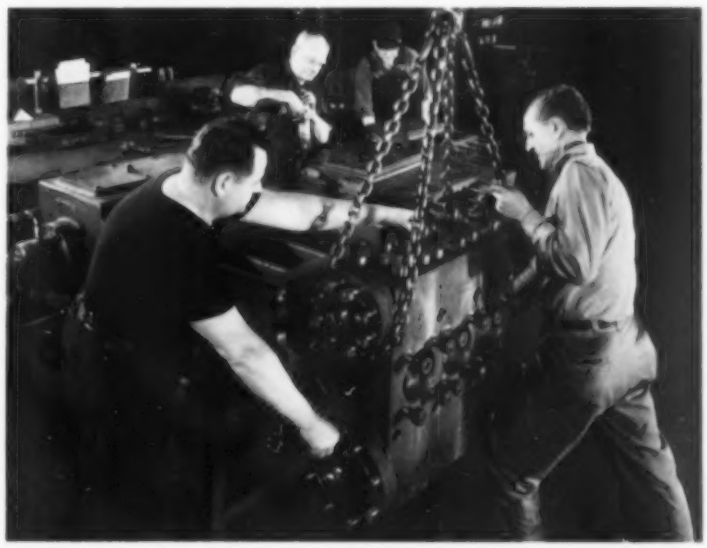

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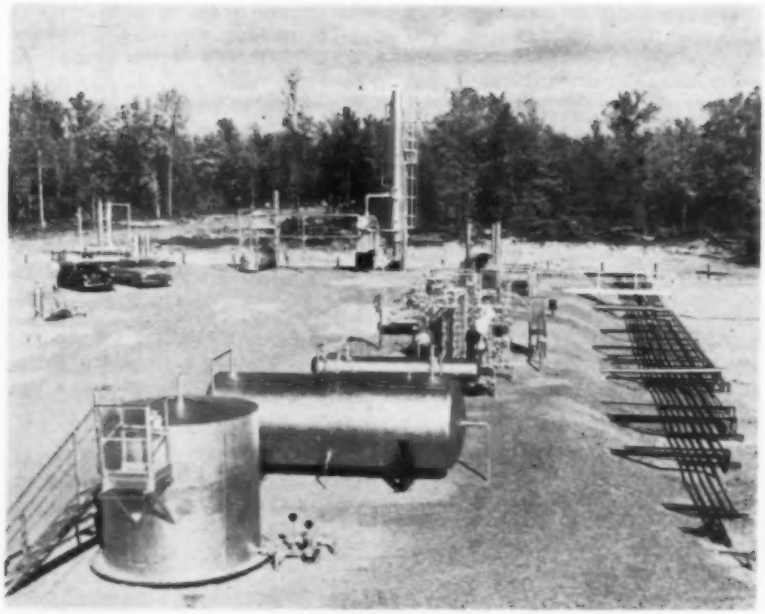

FIG. 4. Located on the only high ground of the river bottom lease, South Hallsville low temperature separation-stabilizer plant is layed out for semi-automatic operation and easy maintenance.

that a 5 F approach heat exchanger was preferred.

Although the initial flowing pressure at the unit was expected to be about 2300 psig, the heat exchanger finalized design would give a minus 20 F separator temperature until the flowing pressure declined to about 1950 psig. This is with the qualification that the inlet well stream temperature would not be over the expected maximum of 100 F or the separator pressure over 1000 psig. The separator temperature would increase in practically a straight line function as the flowing pressure fell below 1950 psig as shown in Fig. 3. When the flowing pressure equaled the sales line pressure (which was expected to be 800 to 1000 psig), the separator temperature would equal the well stream inlet temperature.

Experience dictated that to obtain a minus 20 F separation temperature with the 100 bbl per MMscf initial liquid content, all of the free liquid would have to be by-passed around the heat exchanger and choke. This by-passing would allow a greater Joule-Thompson effect to be obtained across the choke than with the liquid present. Also, due to the reduction in heat load, any given size heat exchanger would be more effective in reducing separator temperature; or rather, a much lower average separation temperature would be maintained. A primary total liquid knockout was utilized to remove all free liquids ahead of the heat exchanger. The handling of these liquids will be discussed in detail in another section.

The unit was designed to handle a maximum of 10 MMscf per day. So, the heat exchanger also had to be designed to handle that maximum. However, in heat exchangers of this type, the maximum rate does not always determine the maximum exchanger area. Since delivery rates from this type installation can fluctuate widely due to seasonal demand, it was also necessary to determine a minimum flow rate for design. In this case, a 5 MMscf per day rate was selected as minimum. And this rate actually determined the design area of the heat exchanger type used.

As in all heat exchangers, maximum allowable pressure drop is a consideration. Overall pressure drop in this case was limited to 75 psi at the 10 MMscf per day sales rate. It is usually less detrimental to take large drops on the well stream side of the exchanger than on the sales gas side since a pressure reduction has to be taken on the well stream anyway. The heat exchanger purchased was calculated to have 70 psig drop on the well stream side and only 5 psig drop on the sales gas side.

Another prime consideration in LTS heat exchanger design is flexibility. Flexibility was especially needed in the South Hallsville unit since four widely spaced wells were to produce through it. It has proved good practice in the past to design the large exchanger into banks. Each bank should handle no more than 5 MMscf per day. A heat exchanger consisting of one bank of sections to handle the maximum and minimum rate conditions for the four wells could have been used. However, if one well is lost, there would be trouble with minimum rate. The large single bank exchanger would be undersized and unusable.

The heat exchanger that was purchased consists of two parallel banks of sections, each to handle 5 MMscf per day maximum and 2.5 MMscf per day minimum rate. If a well is lost or if it becomes necessary to split one low-pressure well out and handle it separately with a multiple pressure system, the two banks can be split. One bank would be blanked off and isolated in the first case, or in the second case, one bank would be split off and used in a separate pressure system. This insurance cost very little more.

Liquid Handling

The unusual liquid handling possibilities in the South Hallsville installation deserve special mention. Even though this handling is not totally original, it does affect considerable flexibility. As mentioned before, a total liquid knockout is used to remove free liquids (condensate and water) from the well stream. This vessel operates at full well flowing pressure. The liquids removed are passed to a secondary free water knockout which operates at separator pressure and discharges the free water to the pit. The secondary free water knockout is a bit unusual in that it can be operated to pass the flash gas and condensate on to further processing in three different ways.

The vessel itself is a monotube with internal baffling designed for easy level control. Each end is baffled with one end arranged to handle and discharge water with a gas-water interface control. The other end handles condensate with or without a liquid level control depending on where the condensate is routed. At all times, the gas flashing in the vessel is routed into the top of the cold separator for dehydrating and stripping. This gas outlet extends down into the vessel and the lower end sticks into an upright movable bucket. The bucket is attached to a threaded shaft which run through a packing gland in the bottom of the vessel. By screwing the shaft in or out, the bucket can be moved up or down. When the bucket is all the way up, only gas leaves the knockout. Condensate will leave the knockout with the gas if the bucket is moved down until its upper rim is below the condensate level. It is possible to route the condensate to three different places by the use of this feature.

Originally, gas and condensate were routed together into the top of the cold separator. This caused the separator temperature at any given set of pres-

sure conditions to be higher than if only the gas were taken over. Due to a decrease in well flowing pressures, it was necessary to change this flow process and to put the liquid into the bottom of the cold separator. This was done by merely connecting a line between the condensate box outlet of the free water knockout and an inlet connection in the bottom drum of the cold separator. The liquid was thus allowed to gravitate from one vessel to the other. The adjustable bucket in the knockout was set to allow only gas to pass through the connecting line into the top of the separator. This allowed the gas zone of the separator to operate about 20 F colder than before. Testing is now in process to determine the effect on recovery.

A third possibility exists for handling the condensate. An auxiliary inlet was put in the stabilizer at the middle tray. Therefore, it is possible to install a liquid level control in the knockout to operate a condensate dump valve. The condensate could then be dumped from the secondary free water knockout directly to the stabilizer.

This third handling method may be used, finally, since placing relatively warm condensate into the bottom of the cold separator does affect a slightly higher separation temperature. As flowing pressures decline, this last method could be used to keep separation temperatures low and recovery high. Much is yet to be learned about these liquid handling methods and their relative recovery possibilities.

Stabilizer

The stabilizer for the South Hallsville unit was designed to handle a maximum of 1000 bbl of product per day. The column is a 20-in. by 30-ft vessel containing 10 trays. The reboiler used is of the external type using 14 psig steam for heating. The steam coil is sufficiently large to maintain a 230 F reboiler temperature using the low-pressure steam. This temperature is required to make the Reed vapor pressure product sold while maintaining a sufficiently high stabilizer pressure so that stabilizer vent gas can be used to operate the glycol injection pumps. Vent gas is used to drive the glycol injection pumps, glycol supply and circulation pump, cooling tower water pump, and to gas lift the water well as well as for fuel in all the fired vessels.

Injected glycol is allowed to pass through the stabilizer with the condensate. It gravitates through the tower into the reboiler. The reboiler has a baffle in one end that is used to direct the flow of condensate from the inlet in the bottom diagonally upward across the heating coil. This is to assure that uniform heating of the bottoms product will occur. The condensate is dumped from the reboiler to the product coolers after it weirs over the baffle into the end section.

The presence of the baffle required that a method be found for getting the glycol in the bottom of the heating section around the baffle so that it could be dumped from the reboiler with the product. Otherwise, the reboiler would fill to the baffle height with glycol and log the stabilizer bottom so that no condensate could circulate. This would disrupt bottoms heating, and stabilization would stop. It was desirable not to use an interface liquid level controller for this because of the rigorous duty.

The problem was solved by installing a U-tube glycol seal around the bottom of the baffle. By making the U-tube the proper length, condensate was prevented from flowing under the baffle through the glycol-filled U-tube at the head differentials in the reboiler. Thus, only glycol could pass through the U-tube into the bottom of the end section. When the stabilizer dump valve opens, the glycol present in the end section is the first thing to be dumped from the vessel.

Two product coolers are used to cool the condensate so that it will be stable in normal lease storage. A gas-

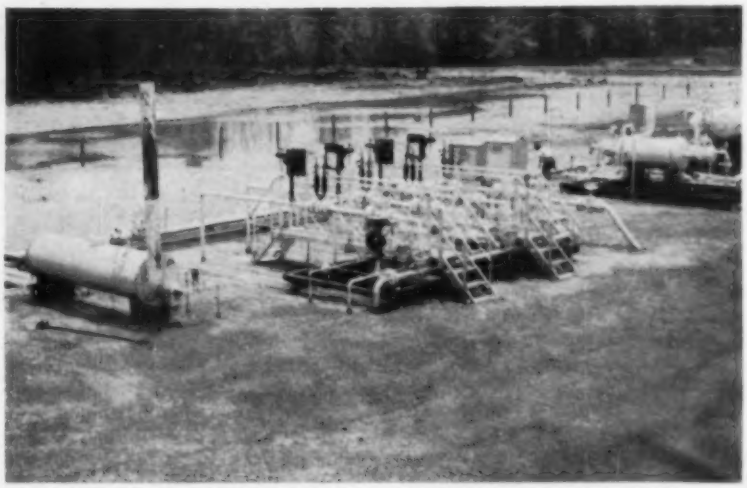

FIG. 5. Due to possible flooding at the well sites, full well stream meter runs and skid mounted test unit are mounted at the central location.

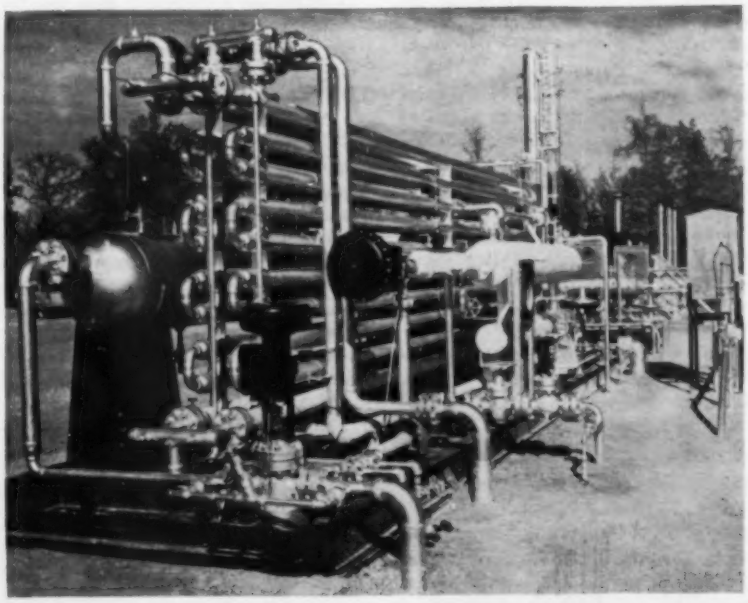

FIG. 6. Heat exchanger and cold separator are skid mounted. A split bank heat exchanger is used to provide flexibility, separator is operating at minus 10 F.

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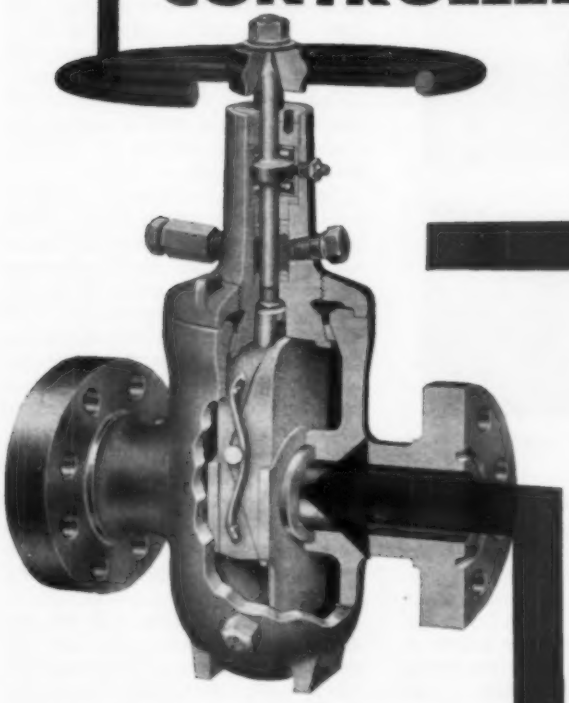

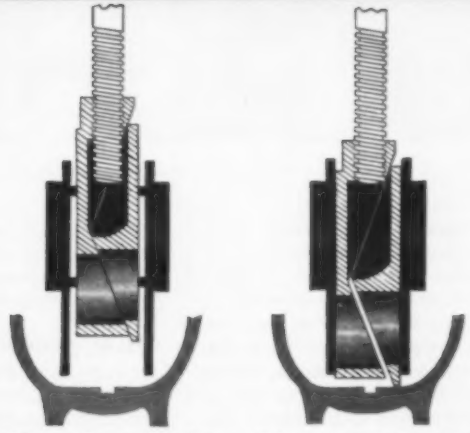

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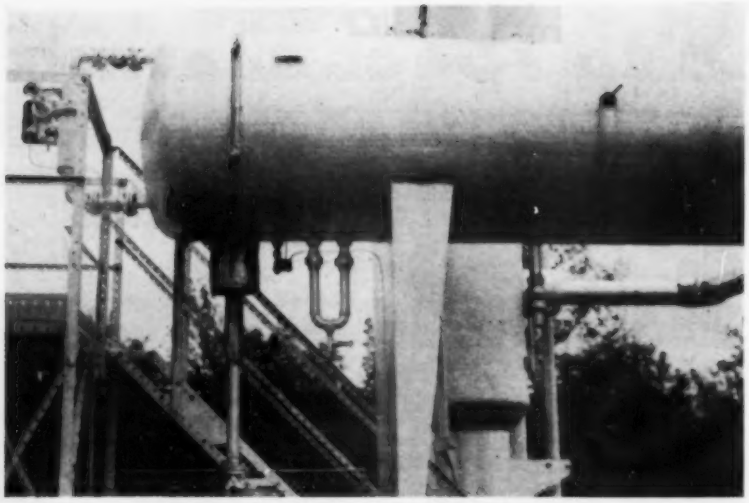

FIG. 7. Unique U-tube seal was used on the stabilizer reboiler to permit dumping glycol with the product.

to-product heat exchanger is first used to cool the condensate from 230 F to about 130 F. A water-to-product cooler is used to decrease the temperature of the condensate from 130 F to about 85 F before it is sent to storage. Water for the water cooler comes from an atmospheric type cooling tower. A gas driven steam pump is used to circulate water through the heat exchanger and cooling tower.

No electricity is used in the unit. All prime movers, controls, and instruments are gas-operated by waste gas from the stabilizer column.

Glycol Handling

Glycol injection into the system is made at four points. Since the regenerative heat exchanger consists of two parallel banks, glycol is injected into each bank individually to assure good distribution. Glycol is routinely injected into the line carrying vent gas from the free water knockout to the cold separator to prevent hydrating there. Then, during testing, glycol is injected into the line carrying gas from the test system to the cold separator. This is done to prevent the moist test gas from freezing when it contacts the cold well stream entering the low temperature separator.

The glycol injection is accomplished with the use of three double acting pumps. These pumps are manifolded in such a way that each end of each pump can be used for any service. To do this without damaging the pumps, it is necessary to keep both ends of any one pump pumping against about the same pressure. Since we have two injection points in each of two different pressure levels, this can be done quite easily. The pump manifold is also arranged so that both ends of any one pump can be used to inject into any one injection point. The use of the three pumps allows us to have a standby while two pumps are normally pumping into the four injection points.

Injected glycol passes with the produced condensate through the cold separator, stabilizer (as mentioned before), and product coolers into a glycol-condensate separator. This vessel is a large (6 by 15 ft horizontal) settling

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drum which recovers the glycol from the condensate stream to storage. The separator was sized to give about a two-hour condensate settling time at the maximum rate of 1000 bbl per day. The condensate in the vessel is maintained between 80 F and 90 F. Past experience has shown that glycol carryover to the stock tanks is kept to a minimum by this practice. Normal vessel pressure is kept at about 30 psig which is sufficient to feed glycol back to the reconcentration unit.

A 50-bbl welded tank is used to store new glycol for use in the unit. Glycol is purchased in bulk at a saving over the use of drum glycol. Bulk glycol storage is advantageous also because it simplifies handling at the unit and the addition of new glycol to the system. Use of the bulk glycol storage method saved considerable time and money in the initial unit charging alone.

A gas motor-driven rotary pump is used to add new glycol from the bulk storage tank to the system. The pump is also used to circulate the bottoms of the condensate storage tanks into the glycol-condensate separator. This is done to put any carried-over glycol back into the system. The stock tanks were provided with cone bottoms to facilitate circulation.

The glycol reconcentration unit uses a direct fired cylindrical heating section with a still column and flash tank mounted on top. A glycol surge tank is mounted beside the reconcentrator. Lean glycol flows to the tank through a syphon pipe system that maintains the proper level in the reconcentrator. The glycol injection pumps take suction from this surge tank which contains internal coils. Cool rich glycol flowing through these coils cools the lean glycol before it is pumped. A level control operating a valve in the rich glycol line maintains the proper level in the surge tank. By controlling glycol level in the surge tank, a large glycol storage volume can be maintained internally in the system. The combined internal storage of the glycol-condensate separator and glycol surge tank provides a good safety factor in the event of abnormally large glycol losses. This is almost a necessity since the unit has an operator in attendance only six hours a day.

The performance of the glycol system has been good. Since the plant was started up in September 1956, glycol usage has averaged 1.33 gal per 100 bbl of condensate produced. We feel that this is mostly due to the design of the system. Our glycol handling method specifically aims to minimize glycol loss with the condensate sold and waste due to handling. To do this, we (1) provide adequate glycol separation, recovery, and handling facilities as a part of the unit, and (2) use as low a glycol concentration as possible for injection. Glycol concentration for this unit has been maintained at about 70 percent since start up.

Operator Training

No matter how good the design, the successful operation of LTS equipment depends largely on the "know-how" of the operators. Well informed operators and supervisors will get the most out of their equipment. They should know the process, the function of the various vessels, and the operating characteristics of the components — all before the plant goes onstream.

During the plant construction period, Atlantic issued a comprehensive illustrated operator's manual for the operators and supervisors. The manuals contained simplified process and equipment description, job breakdowns for each operation, and trouble shooting charts. Just before the plant was placed onstream, two training sessions were held. The first was classroom type instruction in LTS process theory and operating description. The second session was on-the-job training to familiarize the operators with actual operation and adjustment. The training is paying dividends in excellent plant operation.

★ ★ ★

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"Best Balls and Seats in the Oil Patch"

"Jim Woodruff" Joins Penrod Drilling Fleet

The "Jim Woodruff", Barge No. 48, has been completed, christened and delivered to the Penrod Drilling Company of Shreveport, Louisiana. The christening ceremony was held June 11 at the Bethlehem yard in Beaumont, Texas.

The "Jim Woodruff" will be able to drill in 75 ft of water in the open sea. The submersible barge is generally similar to the "S-55" of The California Company, for whom it will drill under contract. It is 190 ft long overall and has a beam of 150 ft. Depth of the hull is 12 ft.

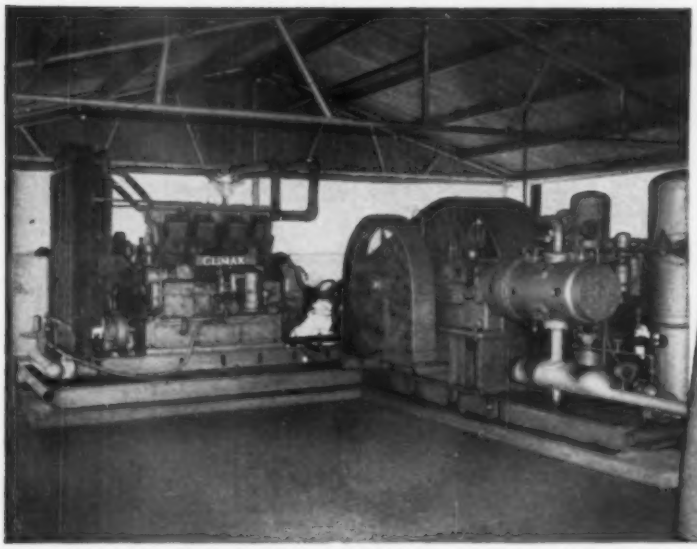
The new Penrod vessel is of the self-stabilizing submersible type, with streamlined anti-scouring hull of large bottom area, suited for the particular soil and weather conditions found at those locations in which she will work in the Gulf of Mexico.

Drilling machinery on the "Jim Woodruff" consists of a diesel-electric driven drawworks, 27½-in. rotary table, two main mud pumps, each with rated output of 1000 hp, and a four position derrick rated at 1,000,000 lb lift. The rig will be powered by diesel-electric drive, using eight shunt wound motors. The main power plant consists of five diesel engines each driving a 500 hp d-c generator. Excitation will consist of two a-c motor driven 40 kw d-c exciters.

Auxiliary power and lighting will be supplied by three diesel engines driving 300 kw, 3 phase, 60 cycle, 480 v a-c generators and attached exciters.

The ram columns, rams and major members of the load bearing structure are constructed of "Tri-Ten" steel, and the deck house sides are of plate aluminum, in order to obtain highest strength with lowest weight.

Crew quarters, offices, dining salon and recreation room are air conditioned; provision has been made for well surveying and logging unit and a cementing unit; three vapor-compression distillation units provide a total of 21,600 gal of fresh potable and drilling water per day; and a 60 kw a-c diesel generator has been provided for starting up cold, and for emergency.



One of two Climax V-85 installations at Tex-Penn's Plymouth Field near Corpus Christi, Texas. Engines drive gas compressors on a closed jet system.

Climax Engines are

FIELD RECOMMENDED

Mr. F. F. Dueser, Production Superintendent, Tex-Penn Oil Co., Corpus Christi, Texas, states that he is "well satisfied" with his Climax engines. Both V-85 Units operate on a 24-hour per day, 365 day yearly basis and minimum downtime has been encountered since installation. "In addition, my Climax engines give excellent performance, operate at low cost per horsepower and are dependable," comments Mr. Dueser, "and I strongly recommend them for any similar oil field applications."

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- *All cylinder heads have Climax high-turbulence type combustion chambers which produce maximum fuel economy.*
- *All models have the Climax consistent design that makes possible maximum interchangeability of wearing parts.*

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This Wheland HP-8000 handles above average pressures for slim hole operations, yet is easily portable according to Mr. Harold Black, Owner (right). At left is Mr. W. E. Riley, Pusher.

Here is Black Drilling Co.'s streamlined unit, which was designed around their efficient HP-8000 Wheland Pump.

P. O. Box 605

Phone 23

Black Drilling Company

ALBANY, TEXAS

June 8, 1957

Mr. Gordon P. Street, President
The Wheland Company
Chattanooga, Tennessee

Dear Mr. Street:

The HP 8000 Wheland Pump, which we put in service in January, is more than meeting our specifications. We required a pump that would handle above average pressures for our slim hole operations and yet adapt itself to our plan of streamlining and portability. Our streamlined unit, which was designed around your pump, has cut our moving and rig-up time by 50% and increased our bit footage and penetration rates by 20%.

The performance of this pump and your field service has more than justified our choice of a Wheland.

Very truly yours,

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Harold Black

Harold Black

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•Greater Portability

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HP-8000 DUPLEX SLUSH PUMP
7-¼" x 12", 220 HP Nominal Input at 70 RPM

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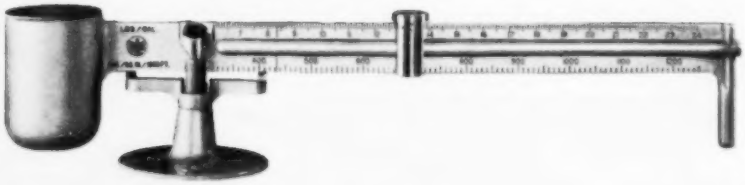
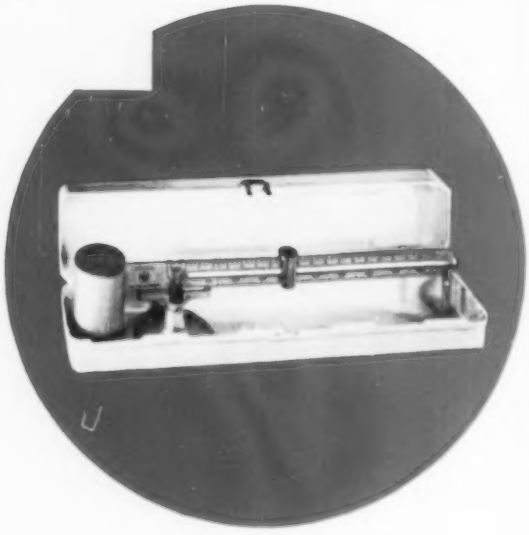
BAROID'S new "Four-Weigh" MUD BALANCE





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This completely redesigned Mud Balance gives you FOUR different scale readings from ONE sample at the rig or in the laboratory. Scales have been extended to give wider ranges than older balances and cover all muds from aerated to heavy. Easier to read, easier to calibrate, more durable . . . screw adjustment for recalibration, instead of former lead shot method. Die-cast metal design assures uniform volume measure. Durable, non-corrodible plastic case also available.

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5791

Homemade Down-Hole Camera Aids . . .

Cable Tool Fishing Job

• Manufacturers Light and Heat Company employees use clever photo idea to take pictures in 844-ft well to spot lost tools

FIG. 1. **Lost tools** were found in this picture, taken by the special downhole camera. Top of the cave is defined by the roughly circular line separating light and dark areas. Some 15 ft of stem is showing. The water, its surface flecked with oil, is 54 in. across. Height of the cave is 25 ft.

RETRIEVING lost drilling tools has been made possible, or at least easier, by underground photography. Employees of Manufacturers Light and Heat Company, Pittsburgh, Pennsylvania, have used pictures to locate lost cable tools in a well near Seatonville, West Virginia.

The company's unique addition to its list of fishing tools, a specially rigged camera, is responsible for locating a bailer and drilling bit at a depth of 844 ft. The two elusive fish in this case were found lodged in a pool of water beneath a ledge of a large subterranean cavern. The tools were lost while cleaning out the well in the Majorsville Storage field in Marshall County, West Virginia. Forty years ago the well produced oil and gas; it has been converted for gas storage.

This subsurface photography experiment has rendered this particular operation successful—and also produced a workable device and a lot of "technique" that will prove valuable in dealing with cable tool fishing jobs in the future.

Although downhole photography is not unheard of in the oil industry, most experience in the past has been limited to taking pictures on a horizontal plane for the purpose of studying formation structure.

Originator of the underground photographic reconnaissance was Ray Reynolds, a tool foreman for Manufacturers Light. When all standard fishing procedures had failed to locate, much less recover, the lost tools, Reynolds took the problem and his idea to superintendent of Division 5, Robert S. Bauman. In turn, he consulted Charles Arnold, head of the graphic arts department of the Observer Publishing Company in Washington, Pennsylvania.

Operational Problems

First obstacle the group encountered was in designing a suitable enclosure to house the camera and photoflash unit and send them safely down the well bore.

To protect the camera, a length of 8-in. pipe was belled-out to 10-in. at the base and hooked to a drilling stem. Inside of the pipe was coated with aluminum paint to reflect the light.

The pipe was slotted at the point where the camera was screwed to the platform — giving easy access to the filmholders.

Second problem was to get the camera to operate once it was in position. This was solved by using a modification of an obsolete photographic interval timer. Wires were run from a battery on the timer to the camera's shutter. After the pre-set period of time had elapsed, current through the wires set off the light.

On each occasion, the camera was lowered into the hole with the shutter open. As little light penetrates the hole, no image would show on the exposed negative until the flashbulb went off.

Initial attempts at getting a picture of the hole were unsuccessful. Several times the housing caught on collar recesses and shelves, setting off the timer prematurely. Once the clock stopped because of centrifugal force produced when the weight of the tools started them spinning on the drilling line.

BLUE

TROUBLED and CONCERNED

over high lifting costs on small volume sandy wells—

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SAND HOG PUMPS

were designed with the elimination of high lifting costs as an objective — the results — a small bore pump so trouble free in its operation that it has actually prolonged the economic life of stripper wells.

The Sand Hog is purposely built with small fluid passages so the velocity of the discharged fluid remains high, preventing any settling of entrained sand. A skirt diverts the discharge of the fluid to a point below the bottom of the traveling barrel—continuously washing the hold-down and flushing the annulus between the pump and the tubing free of sand. The cleanest oil that will separate out of this produced fluid floats up between the pull tube and barrel, and on each suction stroke supplies a film of oil to lubricate and reduce friction between the barrel and plunger.

If you are blue over high lifting costs on low volume wells, ask your Oilmaster Representative to deliver a Sand Hog before your next pulling job and prepare for a change of mood when you compare its trouble-free performance with that of any pump you have previously run.

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FIG. 2. **Camera, flashbulb and timer** were mounted in this length of 8-in. pipe. Note the slot to pull the filmholder.

Negatives were developed near the well. First two successful shots were spoiled by condensation on the camera lens, caused by lowering the air-chilled camera into the warmer temperatures in the well.

The next attempt was completely successful. The picture revealed the bailer and drill in a cave bulging out on either side of the main 10-in. well bore. The tools were off to one side, lodged beneath the roof of the cave. It was this underground cavern that had defied earlier attempts to recover the fish.

David Gumbert, a Manufacturers engineer, used his experience in aerial photography to interpret the picture.

Since it was known that the photograph was taken at a depth of 844 ft, and knowing the dimensions of the drilling stem and bailer, it was estimated that 15 ft of the tools were showing above a pool of water 54 in. across. That placed the floor of the cave at 869 ft.

Recovering the Fish

Armed with the information provided by the photos, personnel again moved to retrieve the tools.

First step was to drive 8-in. casing past the tools to 871 ft — the point opposite the bottom of the tools. The crew then drilled 30 ft deeper.

FIG. 3. **Photographers and assistants** — as well as members of a cable tool crew. These Manufacturers Light and Heat men are (front) John Z. Knisely and Ray Reynolds; and (rear) Fred Haught, George Logue and Shirl Johnson. All had a part in this special fish story.

Then the 8-in. casing was pulled and 4-in. tubing hooked to 10-in. pipe was run down the well.

Attached to the tubing was a wall-hook which the drillers could cant to an angle by pulling on a sand-line tied to the joint.

By using tongs to rotate the tooling and by pulling on the sand-line, it was possible to hook the drill stem and bailer and bring them into the main channel of drilling. Soon both fish were successfully drawn to the surface.

More Photographs

Additional attempts were made to rephotograph the well. Lens condensation caused by the surface and down-hole temperature differential spoiled several exposures. This was overcome by pre-heating the housing for the camera and by keeping the camera warm. Five exposures were then made. Two of them, at 875 ft, showed the tool foremen what they wanted to know: The hole was clean and open. The cleaning out could proceed. The tools were saved.

Acknowledgment

Based on information contained in an article published in "News & Views," April-May, 1957, magazine of the Pittsburgh Group Companies of the Columbia Gas System. ★ ★ ★

better drilling... better logging... better completions with CROSSETT Seeco-Mul *emulsifier*

Seeco-Mul is a dry, flaked compound of abietic, linoleic, and oleic acids, wood tannins, and lignins. It effectively disperses the oil content of emulsion mud systems and also has appreciable lubricating qualities which augment the desired lubricating effect of the oil. In almost all areas, Seeco-Mul emulsion muds increase drilling rates, make better hole conditions, drill into pay formations better, afford better coring, and protect the pay zone from water more effectively. Seeco-Mul readily emulsifies Diesel or crude oils in sodium or limed muds, it is temperature-stable, it has a low water loss at high temperatures, and any qualified mud engineer can use it without special instructions or extra equipment.

Seeco-Mul emulsion muds minimize hole enlargement, reduce water invasion of pay sands, allow better completions in zones with low pressures and low permeabilities, and allow wells to come in on production better, easier, and cleaner. The same logs as run in fresh water muds are entirely suitable in emulsion muds. Seeco-Mul muds often allow better logs to be obtained because the emulsion does not block the formation as in the case of water systems. Seeco-Mul increases the wetting action of the mud on the drill bit and the collars, which results in less drag, less torque, less balling of the bit on bottom, and fewer round trips.

Seeco-Mul has a number of other operating advantages which your local mud dealer will be glad to tell you about — or write to us. We'll be glad to send you illustrated literature and a lab sample without obligation. Crossett Chemical Company Division of The Crossett Company, P. O. Box 271, Crossett, Arkansas.

faster penetration... less balling on bottom less drill stem torque with CROSSETT Seeco-Mul

Frac-Assist . . .

New Down-Hole Fracturing Booster

New gas-generating tool thrusts fracturing fluid into formation in a single 5000 hydraulic horsepower "punch"

HIGH injection fracturing is receiving a boost from a new down-hole tool that yields an additional 5000 hydraulic horsepower push to the normal fluid frac stream.

The device is the Frac-Assist, developed by BJ Service, Inc., Long Beach, California. The tool is a packaged power unit that is placed in the tubing string through which the fracturing fluid is pumped. It is positioned immediately above the perforated tubing opposite the zone to be fractured. After the fluid has been pumped to the zone, it is then "assisted" into the formation by the new tool.

The power-packed tool is "shot" at the surface by introducing a triggering plug into the frac stream. When this plug enters the tool, it compresses a firing cam and detonates blank cartridges which initiate a controlled burning of a gas-generating fuel.

The gas exerts a large, nearly instantaneous downward surge behind the fluid already in the tubing. This high pressure boost produces an extra fracturing force to open up the formation and make way for uninterrupted pumping flow that continues behind the new tool's one-punch striking force.

Primary purpose of the tool, say its developers, was to eliminate friction and fluid losses inherent in pumping fluid from the surface to fracturing points several thousand feet below the surface.

Tool Fuel

Main problem in its development was in finding a tool that could generate its own high injection rate without creating an explosive force in the well. The answer was achieved by using a new solid propellant fuel, a variation of a rocket propellant being used by the government.

This fuel is an ammonium nitrate blended with an appropriate rubber matrix, and resembles the asbestos wrapping which surrounds the gas-generating chamber of the tool. It cannot be ignited by normal shock, friction or normal heat. In a demonstration of the fuel, a sample was struck with a hammer, rubbed with sandpaper and exposed to open flame. An igniter strip is used to "fire" the fuel in the tool, producing a controlled even burning. The fuel will burn and will not detonate at temperatures of 300 F and 10,000 psi. It is classed for ICC shipment as a Class "B" propellant explosive and listed as inflammable. About 50 lb of the gas-generating fuel is used per job, at present, although larger quantities are considered safe.

Firing

The tool is fired by a mechanical motion that can only be originated by a plug being pushed through the tubing and passing through the tool. The tool is not armed until it is actually lowered into the well and only the firing head protrudes above the wellhead. At this point the initiating charges are inserted.

Two Sizes

The manufacturer assembles the fracturing booster in two sizes. One is 4¾-in. diameter and is designed to run in 5½-in. casing. The other tool has a diameter of 5½-in. to be used in 7-in. casing or larger. The smaller tool is run on 2-in. EUE tubing or larger. The larger tool uses 2½-in. EUE tubing or larger.

Several different makes of packers have been used in field tests, all of which were of the full bore retrievable type. In these tests, the developers say, no difficulties have been experienced in releasing any of the packers nor has any packer sustained any damage.

Placement

The packer and the Frac-Assist tool, which is placed immediately above the packer, are set up in the hole from the perforation a distance in the casing equivalent to the anticipated displacement volume of the tool.

In a well having a 3000 psi bottom-hole pressure, for example, the tool would be set 16 cu ft above the perforations. If this were 7-in., 23 lb per ft casing, this would be about 75 ft above the perforations. If it were 5½-in., 17 lb per ft casing, it would be about 125 ft above the perforations.

The anticipated displacement at various pressures can be predicted from a

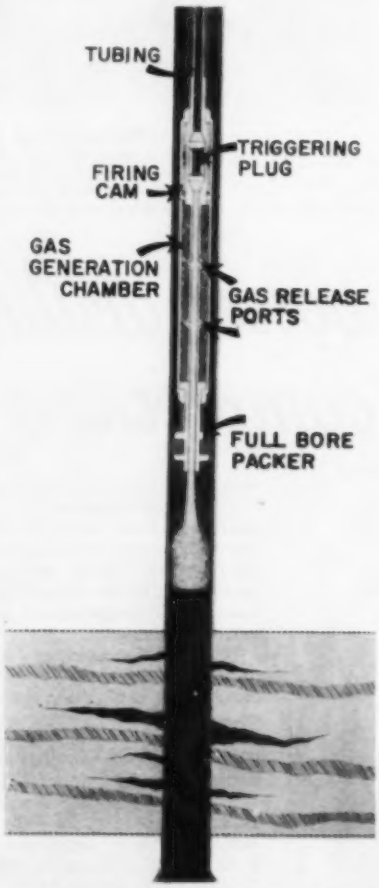


FIG. 1. Solid fuel inside the Frac-Assist is ignited by pumping a rubber plug from the surface into the tool. Gas is then formed inside the chamber until reaching a fixed pressure, resulting in a sudden burst of pressure sending frac fluid into the formation with greatly increased thrust. The triggering plug is pumped on through the tool and into the bottom of the well and normal pumping is continued.

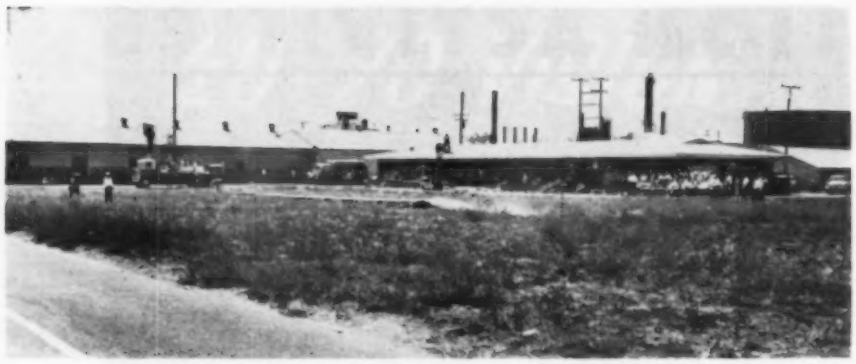
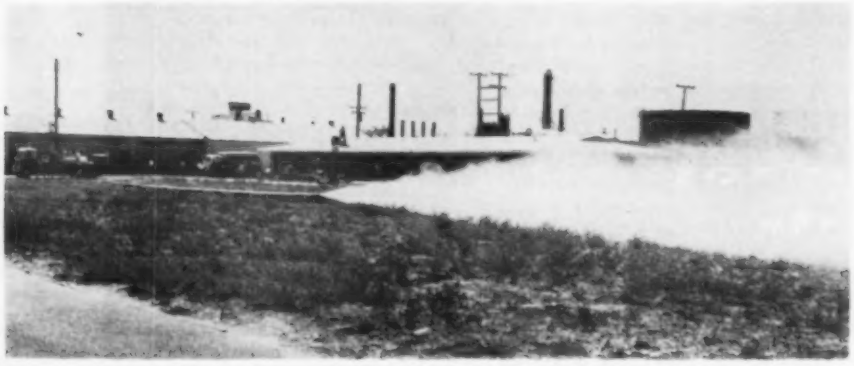


FIG. 2. **Surface demonstration** of the frac booster shows simulated down-hole fracturing under normal pumping through a small orifice, sending a stream of water at 6 to 6½ bbl per min a distance of 25 ft, then . . .
Whoosh! A few seconds after the triggering plug is pumped "down-hole," Frac-Assist takes effect and sends spray 125 ft.



"Pressure × Volume = Constant" relationship. Since the tool generates 16 cu ft at 3000 psi, the constant is equal to 48,000. Then PV = 48,000, and any pressure can be inserted and the anticipated volume computed.

Frac Fluids Used

Fracturing fluids injected have varied in these field tests from thickened oil carrying one pound of sand per gallon, to lease crudes carrying two pounds of sand per gallon, to water with no sand.

Field Tests

Frac-Assist tools have been successfully used in several field tests in three states.

On a well in the Wilmington field, Los Angeles County, California, the new tool effected a breakdown of formation, not possible under normal fracturing methods.

A Rice County, Kansas, well responded to treatment with the new tool by doubling the amount of sand and oil that could be put away into formation.

A test with the Frac-Assist on a Farmington, New Mexico, gas well recorded increased pulse pressures while pumping from 2000 psi to a peak of 5000 psi, as the tool responded. Pumping was then continued at the same rate, but at 1650 psi. ★ ★ ★

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EXPLORATION ACTIVITIES

TEXAS

★ A 644 bbl per day discovery well in Upton County has been completed by Pure Oil Company and associates. The find is on a 1280-acre tract 8 miles southwest of the Sweetie Peck field and 35 miles south of Midland. Initial potential test was taken through a ¾-in. opening through perforations in the Pennsylvanian lime at 9597-621 ft. Oil gravity is 40 deg. Sharing with Pure in the discovery are TXL Oil Corporation, Gulf Oil Corporation and H. L. Brown.

★ Texam Oil Corporation, San Antonio, Texas, has reported potential of the No. 1 Harding wildcat in Atascosa County. It was officially potentialed for a daily production of 76 bbl of 39 deg oil on a ⅛-in. choke. Production is from perforations 5074 to 5090 ft in the Escondido sand. This new discovery is located about one mile southeast and across a fault from Texam's production in the Galba field. Texam owns a 50 percent working interest in 280 acres and a 75 percent working interest in the 40 acres that are potentially productive.

★ Parker Petroleum Company, Inc., of Ponca City, Oklahoma, is drilling below 7-in. casing, cemented at 10,794 ft, in its Ben Hill No. 1-A well in Roberts County, Section 146, Block 42, H & T. C. Survey. This wildcat replaces the original Parker Petroleum Ben Hill No. 1 well, located six hundred feet to the southwest. In the drilling of the first well at 10,954 ft in the lower Morrow Sands, it blew out on January 18. This well, with pressures in excess of 5600 psi, raged against control for 11 days, and defied all attempts to save the well. Finally, it was plugged and abandoned on May 25 and the rig was skidded to the location of the No. 1-A. The Ben Hill No. 1-A found some 20 ft of gas-bearing sand in the upper Morrow zone from 9819 to 9839 ft. This sand was not developed in the original well. In striking similarity to the abandoned hole, a blowout occurred from that depth in the new well; however, crews brought it under control within three hours. The well will be taken to a depth in excess of 11,000 ft. It is anticipated by company geologists that the top of the expected pay zone will be found at 10,905 ft.

★ The Payne No. 1 well in Roberts County, being drilled by Keating Drilling Company of Tulsa, Oklahoma, indicates a new natural gas discovery southeast of the Lips field. A drillstem test, at 10,230 to 10,310 ft, flowed at an estimated rate in excess of 5,000,000 cu ft per day through a 2-in. choke. The operator is continuing to drill to a depth of 10,500 ft. Keating Drilling Company controls leases on approximately 3000 acres at the location of this well. NI-Gas Supply, Inc., a subsidiary of Northern Illinois Gas Company, is one of the participants in the group for which Keating Drilling Company is the operator. The Payne No. 1 well is the fourth drilled by NI-Gas.

★ A wildcat gas well in Parker County, which on drillstem test showed an estimated natural flow of 3,000,000 cu ft per day, is being completed by Reiter-Foster Oil Corporation. After treatment, officials say, the well should produce at the rate of 10 to 15 million cu ft of gas per day. The discovery is located in the center of a 10,000 acre block, which has just been acquired along with other properties by Reiter-Foster from Advance Petroleum Corporation. It is 15 miles from the nearest comparable production, and was brought in at a depth of about 5100 ft from the Atoka conglomerate.

★ Gas discovery was made in Terrell County by Magnolia Petroleum Company and the Western Natural Gas Company. Gas, flowing at an estimated rate of 75,000,000 cu ft per day, was struck just below 12,400 ft, he said. The well is the Magnolia-Western Natural Gas No. 1, Brown Bassett Estate, located in the Goode Ranch area of Terrell County. The well blew out immediately, catching fire and destroying the rig. Company officials termed the discovery "of unquestionable major significance." The well was being drilled by Magnolia Petroleum Company under a farm-out agreement made with Western Natural Gas approximately a year ago. Under this agreement, Magnolia undertook seismic and other exploration of the area and agreed to drill a well to 15,000 ft, in exchange for half interest in the producing property. Officials reported there was a drilling break of only about 5 ft. The well was completed in the Devonian formation.

OKLAHOMA

★ A new gas reserve in McIntosh County has been tapped by Oklahoma Natural Gas Company at its No. 1 Popejoy, NW SW NE 17-10n-13e. Well is southeast of the Kusa gas area and northeast of Dustin. Discovery gaged 3,000,000 cu ft of gas per day on drillstem test with tool open 1 hour. Flowing pressure was 200 psi in 5 minutes, increasing to 322 psi in 20 min. Shut-in pressure was 1240 psi in 15 minutes. This test was in the Gilcrease at 2751-65 ft. Well is being drilled to a contract depth of 4100 ft in the Wilcox. Additional drillstem tests were taken in the Union Valley and Cromwell. Union Valley was topped at 3006 ft, and the Cromwell at 3155 ft.

★ Cities Service has staked a deep test on its 77,440-acre North Guymon block in Texas County, in the three-state Hugoton gas field. The test, Murdock No. 1, is 10 miles northeast of Guymon, and will test the Morrow sandstone and Chester limestone, drilling to the Meremac, expected at 6800 ft. This is the first deep test on Cities Service's 77,440-acre drilling block and is located in the center NE SW Sec. 10-4n-15e.

NORTH DAKOTA

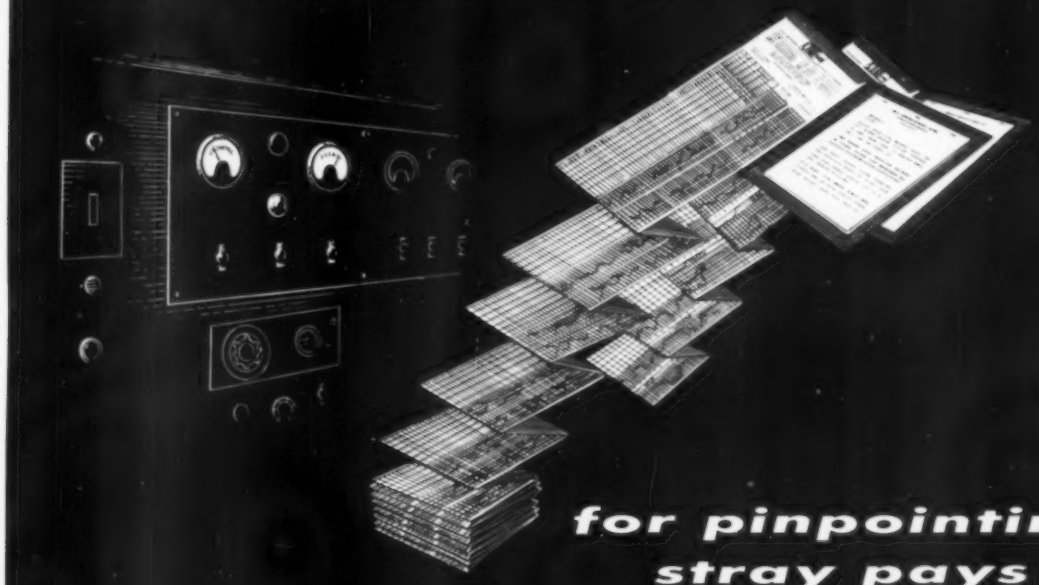
★ New depth mark for the state and the Williston Basin has been set by Amerada Petroleum Corporation at its geological wildcat in the Beaver Lodge field of Williams County. The company's No. 9-A North Dakota State is still drilling below a record 14,828 ft. It is the deepest well yet drilled by Amerada.

★ Cities Service is locating a Mississippian test on its 6700-acre block near the Canadian border in Rolette County, North Dakota. The test is 15 miles southeast of Mississippian production in the Lulu Lake field of Manitoba Province, Canada, and is approximately 135 miles northeast of Bismarck. Located in the center NW NW Sec. 16-162n-71w, the test will be drilled to a projected depth of 3500 ft.

NEW MEXICO

★ Under a joint venture agreement, Quinta Corporation of New Mexico and Phillips Petroleum of Tulsa, together have leased six sections of land in McKinley County from Yucca Mining & Petroleum Co., Inc., Albuquerque, New Mexico. The sections are located in Township 16 North, Ranges 15 and 16 West. According to the terms of the agreement, Yucca Mining & Petroleum retains a gross royalty interest and receives a substantial sum plus Quinta stock. At the present time three drilling rigs are operating on these properties to complete a thorough exploration program.

20-20 VISION...



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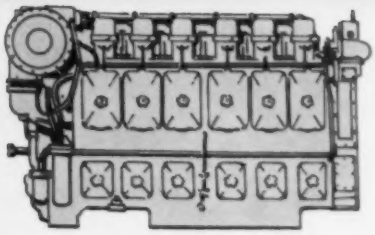

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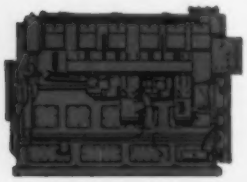

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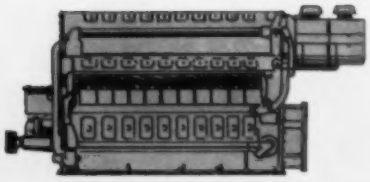

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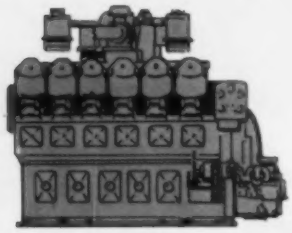

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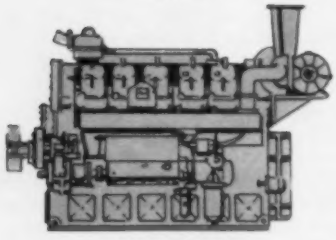

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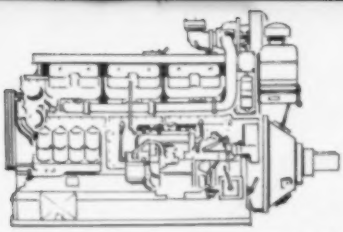

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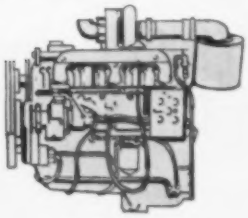

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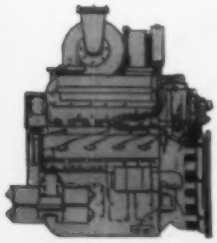

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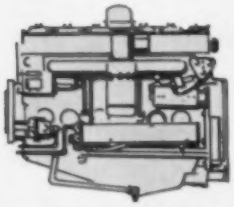

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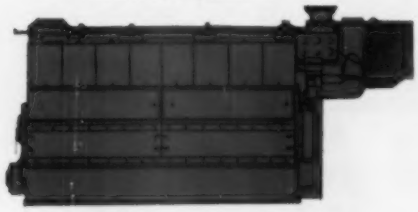
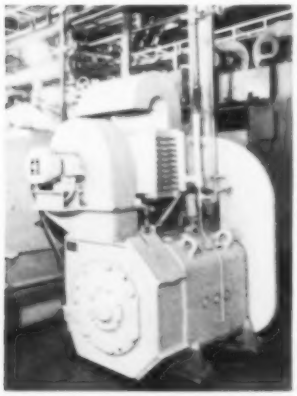


WHITE-SUPERIOR

LOUISIANA DELTA OFFSHORE CORP. RIG DELTA NO. 1 equipped with ALCO engines and General Electric drive. Operating as drilling contractor for oil producers, the rig is located forty miles out in the Gulf of Mexico off the Louisiana Coast from New Orleans. **LEFT . . .** Some of the popular oil field engines with which General Electric drive can be mounted.



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CANADA

★ Union Oil Company and its partners — Hudson's Bay Oil & Gas Co. and Home Oil Company — have made an improvement oil discovery in the Virginia Hills area of Alberta Province. The jointly-owned wildcat produced 36 deg clean oil at the rate of 1200 bbl a day on formation test. On the initial test with 14/64 in. choke the well flowed 23 bbl an hour; on the second test with 32/64 in. choke it flowed 32 bbl an hour; on the third test with 44/64-in. choke it produced 50 bbl an hour. Each of the companies has a one-third interest in a four-township lease embracing 92,160 acres immediately adjacent to similar acreage sold by the Alberta Government recently to the Pan American Petroleum Corporation and British American Oil Company for $3,351,859 and another 92,160 acres sold by the government to Mobil Oil Company of Canada for $2,314,137. The wildcat was first drilled last winter but could not be completed before the spring breakup. At that time a drillstem test showed 6200 ft of clean oil. Total depth of the wildcat is 10,624 ft with perforated pipe at the 9238-9282-ft interval.

★ The Atlantic Refining Company is expanding its search for oil in Canada to the provinces of Alberta and British Columbia. Atlantic has joined with Tidewater and Samedan oil companies in acquiring a second tract of 6560 acres in the Pembian-Keystone area of Alberta. Two indicated producing wells, drilled by other companies, offset this new acreage. It is also reported that together with the Mobil Oil Company, Ltd., Atlantic was the successful purchaser of approximately 92,000 acres in the Pembina-Keystone area of east of the Sturgeon Lake field in Alberta. A successful exploratory well was recently completed by another company about one mile from this new acquisition. To coordinate this expanded program Atlantic is establishing a district office at Calgary, which will be manned by geological, geophysical, and land personnel. Previous to these new acquisitions Atlantic's activities in Canada have been limited to Saskatchewan.

LOUISIANA

Discovery of a new oil field 39 miles offshore Louisiana in the Gulf of Mexico by the CATC Group, is marked by the dual completion of Well OCS 0494 No. A-1, at a rate of 344 bbl a day. The well, in the Vermilion Block 120, is a rank wildcat located 6 miles from nearest production, in an area in which the CATC Group has 20,000 acres. The well produced at the rate of 192 bbl a day of 42.6 deg oil on an 8/64-in. choke through perforations at 8624-8629 ft, and at the rate of 152 bbl of 42 deg oil through perforations on an 8/64-in. choke at 8598-8606 ft. The well was drilled in 65 ft of water.

★ Rimrock Tidelands, Inc., has commenced operations on an exploratory well in the Northwest Delta Farms area of Lafourche Parish, 22 miles south of New Orleans. Located in SE/4 of Section 27, Township 16 South, Range 22 East, Lafourche Parish, the test well is on a 2100-acre farmout from the California Company. Following the dredging of a short canal to the drilling site approximately two miles from Lake Salvadore, drilling crews spudded in on August 5. To be drilled from an inland barge rig, the test well, the Rimrock-Calco-W. Alton Jones No. 1, will probe the sands of the Miocene section.

WYOMING

★ Falcon Seaboard Drilling Company is drilling a 7500-ft Parkman sand test well in Campbell County, after acquiring 720 acres of oil and gas leases through farmouts from Sinclair, Shell, Dow Chemical, Mobil and Armer Drilling Company. Falcon will retain half interest in the well after selling the other half to Gulf.

★ Cataract Mining Corporation announces the acquisition of a one-quarter undivided interest in a test well for oil and gas now being drilled in the northeast quarter, Section 26, Township 26 North, Range 116, Lincoln County. The purchase of the leases from Western Exploration Company involves 2538.35 acres including the drilling site. The status of the well as of August 1 shows drilling below 1470 ft with slight oil stains and bubbles on slush.

UTAH

★ Carter Oil Company has indicated an oil discovery 10 miles west of the Aneth pool in San Juan County. The wildcat, the No. 4 Bluff Bench Unit, NW NW 20-40s-22e, recovered 1020 ft of free oil on drillstem test of the Paradox at 6502-26 ft. Carter holds more than 500 acres in the area.

★ Pumping unit is being installed at Pure Oil Company's new discovery prospect 14 miles southwest of Moab in Grand County. Well is being completed in the Mississippian, following swabbing of 40 deg oil at the rate of 7 to 8 bbl hourly through perforations at 7694-7728 ft. Well previously blew-out at 6367 ft and flowed 5 to 7 million cu ft of gas daily, with oil. Well is on a farmout from King Oil Company and spots 1 mile south of a King Oil dry hole. Completion of the Pure Well in the Mississippian would give the state its first production from that formation.

NORTH AFRICA

★ Plans for a 40 percent expansion of seismic crews by French subsidiaries of Seismograph Service Corporation, Tulsa, have been announced as a result of "terrific" expansion of seismic exploration in the Sahara desert.

"There is no question but what there are large oil reserves in the Sahara," says SSC President C. H. Westby. "Plans for expanded exploration activity are going ahead. These oil reserves are going to mean a great deal to France and the French companies. The French colonies are coming into their own as far as oil reserves are concerned." The increased activity will boost the number of seismic crews to nine, with four of them working in the Sahara. Previous experience in desert seismic work will prove valuable in the Sahara where roads and communications are primitive. "One of our crews had to travel 17 days by truck from Algiers to reach its operating area," he said.

DHOFAR

★ A second oil discovery in the Province of Dhofar, Sultanate of Muscat and Oman, has been made by the Dhofar-Cities Service Petroleum Corporation, a wholly-owned subsidiary of Cities Service Company. Preliminary tests of the second well indicate a producing capacity of 2000 bbl per day of 22 deg oil, at a depth of 3200 ft. Drilling is being continued to a greater depth to test lower formations. The structure, known as Marmul, is approximately 11 miles long and five miles wide, and is located 35 miles from the sea. It is more than 500 miles distant from the nearest oil production in Saudi Arabia. The first well drilled on this structure, approximately two miles northwest of the present well, had substantial oil shows, the later production tests indicated that it also would produce at approximately the same rate. The Dhofar concession was granted by His Majesty Said Bin Taimur, Sultan of Muscat and Oman, and covers an area of approximately 32,000 square miles. The Richfield Oil Corporation has a 50 percent participating interest. Many promising structures have already been outlined within the concession. A heavy rig is now testing one of these prospects while a lighter rig is developing the Marmul structure.

THE OASIS—

A gathering spot for NOMADS

Houston Nomads' guests at the August 12 meeting included (front row) E. S. Hulsman of Shell Oil Company, Bogata, Colombia; J. T. Johnson of Creole Petroleum Corporation, Maracaibo, Venezuela; and guest speaker Chester H. Lauck (Lum of "Lum and Abner") of Continental Oil Company, Houston, and (back row) R. R. Davila, Consul General of Venezuela, Houston; R. Ach of S. N. Marep, Paris, France; R. H. Johnson of Standard Vacuum, Polembang, Sumatra; and Oscar Schuberg of Cal Tex, Sumatra.

Nomad Meeting Dates and Secretaries

New York Chapter, first Monday of the month, Hotel Roosevelt, New York. Executive Secretary, E. W. Hoeppner, in care of Hughes Tool Co., Room 903, 45 Rockefeller Plaza, New York 20, N. Y.

Houston Chapter, September 11, Ye Old College Inn, Houston, Texas. Executive Secretary, Harry E. Estes, P. O. Box 18171, Houston 23, Texas.

Los Angeles Chapter, second Wednesday, Jonathan Club, Los Angeles, California. Executive Secretary, W. A. Sawdon, P. O. Box 848, Hollywood 28, Calif.

Tulsa Chapter, third Friday, Mayo Hotel. Executive Secretary, E. L. Thomas, P. O. Box 3771, Tulsa 9, Okla.

Dallas-Fort Worth Chapter, first or second Monday. Secretary, R. B. Gilmore, DeGolyer & MacNaughton, 5625 Daniels, Dallas, Texas.

Prize winners in the golf tournament held in connection with the eighteenth annual Whing Ding of the Los Angeles Chapter of Nomads at the Lakewood Country Club July 12, 1957. Standing are Bob Crozier of The Texas Company; Lefty Beeson of Specialty Sales Company; Rea Walker, who distributed the prizes; Joe Bergeron of Jet Lube, Inc.; John Finney of S. R. Bowen Company; C. F. Van Loozen of Macco Corporation; Howard Kaylor of Standard of California, and Jim Crosby of Richfield Oil Corporation.
Kneeling are Knight Templeton of S. R. Bowen Company; Paul Bowen of S. R. Bowen Company; Jim Richards of BKS Oil Company, and Bill Huskey of Hillman-Kelley.

Paul Bowen of S. R. Bowen Co. (right) received the President's Trophy from Bob Gaylord of Wagner-Morehouse, Inc., Chapter President, at the golf tournament held in connection with the eighteenth annual Whing Ding of the Los Angeles Chapter of Nomads at the Lakewood Country Club, July 12.

What's doing in DRILLING

★ **Drilling prices** in hard rock country will increase $35 to $45 per day as a result of increased drilling bit prices, says AAODC President Jack Abernathy. The 12.5 percent hikes were announced by leading manufacturers and posted July 26. The increases should be taken into consideration in estimating the cost of new drilling contracts, Abernathy suggested.

★ **Cable tools** are putting down the nation's "most easterly drilling well" in Franklin County, northern Vermont. The wildcat has an objective depth of 9000 ft; the well is already drilling below 1800 ft. The Peter Henderson Oil Company of New York City is operator for the test, located at the edge of St. Albans on a block of acreage assembled by farmers and merchants of that city.

★ **Kansas drilling** has declined 15 percent in the past 12 months, reports the Independent Oil Gas Service. Completions in the first half of 1957 totaled 2045, as compared with 2397 in the same period last year. Drillers cut 7,410,470 ft of hole in the first 6 months of this year for an average of 3624 ft per well.

★ **Silver anniversary** is being marked by the cable tool drilling firm of Bennett Drilling Company of Tulsa. Some 1650 wells have been drilled by the firm since it was formed in 1932 — and has worked over 600 more. Bennett operates seven cable tool rigs in eastern Oklahoma and Arkansas. Firm employs 45 — 20 with more than 15 years of service.

Million dollar fire and eventual successful completion of the Magnolia Petroleum Company and Western Natural Gas Company No. 1 Brown-Basset is being taken "in stride" by company officials. Magnolia officials say the loss ($450,000 in equipment alone), "may be a good thing if it makes some people realize the risks taken by the industry in looking for new fuel supplies." A new 20,000 ft rig has been moved in over the old hole and drilling has resumed at 12,407 ft in the Terrell County, West Texas wildcat. The well blew-out and caught fire several weeks ago as the crew started to core a rich Devonian zone. Operators dropped casing in the hole to plug off the gas and oil. Wildcat is 40 miles northeast of Sanderson and is opening a new play in the basin area.

★ **A stationary pylon-supported platform** for drilling has been approved for construction by the California State Lands Commission. The unit will operate about 2.2 miles offshore of Summerland in Santa Barbara County. It will be used for both drilling and production facilities on a lease held jointly by Standard Oil of California and Humble Oil & Refining Company. Application was made by Standard.

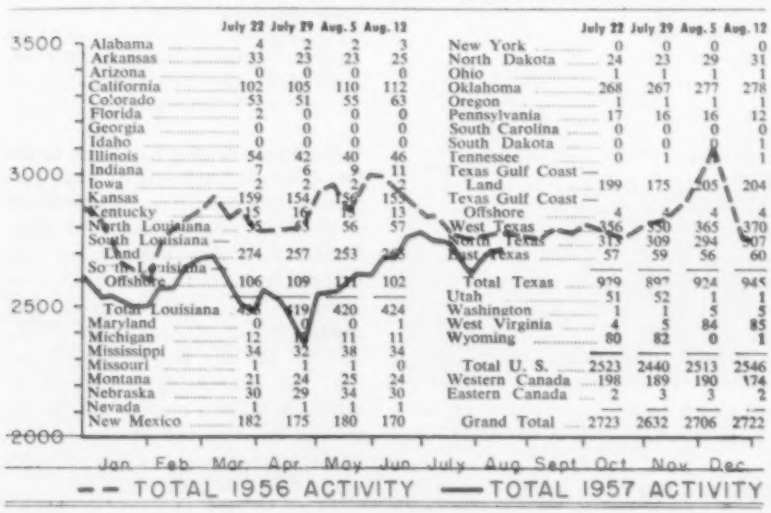
★ **Deeper-than-Texas'-deepest** well is being drilled in Oklahoma by Big Chief Drilling Company. New record holder for the Southwest is Magnolia Petroleum Company's No. 1 Sterba Ordovician, a geological wildcat in the Cement field, Caddo County. In July, the same well broke the Oklahoma deep well record. Well was last reported running surveys at 19,511 ft. Texas deepest well is Magnolia's No. A-417 West Ranch, a 19,060 ft hole in Jackson County. Big Chief's contract on the No. 1 Sterba calls for a 20,000 ft hole.

Rotary Rigs Operating in Oil Fields of United States and Canada

As reported to the American Association of Oilwell Drilling Contractors by Hughes Tool Company

	July 22	July 29	Aug. 5	Aug. 12
Alabama	4	2	2	3
Arkansas	33	23	23	25
Arizona	0	0	0	0
California	102	105	110	112
Colorado	53	51	55	63
Florida	2	0	0	0
Georgia	0	0	0	0
Idaho	0	0	0	0
Illinois	54	42	40	46
Indiana	7	6	9	11
Iowa	2	2	2	2
Kansas	159	154	156	155
Kentucky	15	16	14	13
North Louisiana	55	54	56	57
South Louisiana — Land	274	257	253	265
South Louisiana — Offshore	106	109	111	102
Total Louisiana	435	419	420	424
Maryland	0	0	0	1
Michigan	12	10	11	11
Mississippi	34	32	38	34
Missouri	1	1	1	0
Montana	21	24	25	24
Nebraska	30	29	34	30
Nevada	1	1	1	1
New Mexico	182	175	180	170

	July 22	July 29	Aug. 5	Aug. 12
New York	0	0	0	0
North Dakota	24	23	29	31
Ohio	1	1	1	1
Oklahoma	268	267	277	278
Oregon	1	1	1	1
Pennsylvania	17	16	16	12
South Carolina	0	0	0	0
South Dakota	0	0	0	1
Tennessee	0	1	1	1
Texas Gulf Coast — Land	199	175	205	204
Texas Gulf Coast — Offshore	4	4	4	4
West Texas	356	350	365	370
North Texas	319	309	294	307
East Texas	57	59	56	60
Total Texas	939	897	924	945
Utah	51	52	1	1
Washington	1	1	5	5
West Virginia	4	5	84	85
Wyoming	80	82	0	1
Total U. S.	2523	2440	2513	2546
Western Canada	198	189	190	174
Eastern Canada	2	3	3	2
Grand Total	2723	2632	2706	2722



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Send a generous check to "Cancer" c/o your local Post Office.

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Drilling

★ **Operations will double** for Rimrock Tidelands, Inc., with the purchase of four new deep drilling units to be placed into offshore service in the coming year. The Shreveport, Louisiana, based firm has signed new contracts with Sinclair Oil Company to furnish two additional rigs, necessary management and crews for operations on stationary platforms in the Gulf of Mexico. This will bring to four the number of rigs on contract to Sinclair. In August, Rimrock accepted delivery of a 20,000 ft rig now in operation on a Sinclair 12-well platform on Block 190, 75 miles off the coast of St. Mary's Parish, Louisiana. Another new 20,000 ft rig is to be placed in service in September on Sinclair's 12-well platform on Block 175B, in the Eugene Island area. Rimrock also has under construction a third deep well drilling rig for fulfilling an eight-year-plus contract with Union Producing Company. Fourth new unit is a John Hayward type submersible drilling barge, scheduled for April 1958 launching.

★ **Helmerich & Payne, Inc.,** has purchased drilling assets of Sabine Drilling Company, thus enlarging the fast growing organization to 28 rigs. The firm, which just recently purchased 5 rigs in Venezuela from Sinclair Oil & Gas Company, is a wholly owned subsidiary of White Eagle Oil Company. The purchase from Sabine brings two drilling rigs, together with 30,000 ft of drillpipe and associated equipment, into the Helmerich & Payne family. Both rigs are currently in West Texas, and it is anticipated that these rigs will continue to operate in the same area.

★ **A new inshore drilling barge,** the "Barge St. John," has been accepted by Bay Drilling Corporation. Designed to operate depths to 14 ft, the American Marine-built barge is 175 by 50 by 13 ft. It has a 6-ft sea wall built around the pump room. Named in honor of O. O. (Bill) St. John, drilling superintendent for Bay Drilling, the new inshore craft accommodates a crew of 14 in air conditioned quarters.

★ **California drilling lag** is due to the low price of crude oil on the West Coast, says Stark Fox, vice president of the Oil Producers Agency of California. Fox cites that drilling has dropped from 2605 wells in 1953 to an estimated 2220 wells this year, and production has dropped from 1,000,000 bbl per day to 930,000 bbl per day. Fox suggests that crude prices should be raised 7 cents per bbl to offset cost increases and pointed out that failure to raise prices as cost increases occur was "short-sighted."

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

Power for Venezuelan Platforms. Under construction at Orange, Texas, is this diesel-electric tender for the Offshore Company of Baton Rouge, Louisiana. Unit is destined for Lake Maracaibo, Venezuela, where it will furnish power for a fixed platform. Tender power is supplied by three diesel-electric generating units, each is rated at 900 hp. The diesel-electric tender-platforms are among the first of their kind to go into operation in Venezuela.

★ **Convention time** is nearing for the American Association of Oilwell Drilling Contractors! Final program arrangements are already being made for the seventeenth annual meeting being held at the Mayo Hotel in Tulsa, October 13-15. This year's convention coincides with Oil Progress Week. General chairman is R. E. Kirberger of Service Drilling Company. Registrations for the meeting are being accepted by Housing Committee Chairman Frank E. Frawley, Frank Frawley Drilling Company, Tulsa, Oklahoma.

★ **Turbine drilling** is being tested in Oklahoma by Helmerich & Payne, Inc. A 9¼-in. drill is being used in Shell Oil Company's No. 5 Rumberger, a geological wildcat well in the Elk City field in Beckham County. First trip using the drill was made below 5000 ft, and the well is slated to go as deep as 17,500 ft. Most of the drilling is considered softer than has been found in the other 18 turbo-drilled wells in the U. S. One run, using the drill with a 12¼-in. tri-cone bit, cut 117 ft of hole in 3 hours and 45 minutes in shale and granite wash. Bit teeth and bearing were completely gone, said Helmerich & Payne officials. Weight on bit was 55,000 lb, with mud being pumped at the rate of 850 gal per min at 2300 psi. Two 700-hp engines power the pumps. This flow compares with 750 gal per min at 1400 psi for conventional rotary.

★ **The biggest drilling program** yet undertaken by the Union Oil Company of California will be carried out in the remaining months of this year, officials of the company report. Union is planning to drill 168 wells — 58 of them wildcats. Although much of the activity will be in California, much drilling is promised in the East Lake Palourde, Caillou Island, and Main Pass fields in the Gulf Division, the South Couden and Voss (Tannehill) fields of West and North Texas, and the South Sturgeon Lake field in Alberta, Canada. Major portion of the exploratory wells will be drilled in South Louisiana and offshore in the Gulf of Mexico. Foreign drilling is also anticipated in Costa Rica, Guatemala and continuation of a joint venture in Alaska.

★ **Employees of the Carpenter-Trant Drilling Company,** Denver, Colorado, now have a day off per month with pay. The day off was chosen as a result of recent leadership conferences held for employees of the firm. At the conferences, employees chose to take the day off rather than an hourly raise in pay for the 8-hour day, 7-day week they have been working for a number of years. "We believe this to be something entirely new in the drilling industry," said William H. Carpenter, president of Carpenter-Trant. "Having the men understand the need for increased efficiency in these days of extreme competition makes it more pleasant in the field of employee-management relations. This day off with pay is the first advance in the program we are developing. We trust that it will bring to the drilling industry the ultimate 40-hour week that is enjoyed by so many of the other segments of American industry."

Over the side drilling technique is employed by this floating barge "Champion," currently operating offshore at Galveston and High Island, Texas by Texas Gulf Sulphur Company. The 250 by 55 ft barge is operating in approximately 30 ft of water. The rig carries drilling equipment, crew quarters for 30 men, logging and cementing equipment. The barge is leveled by operation of a ballast motor, pump and tank, then held in place by four 10,000-lb anchors on 1⅛-in. cables.

RUNNING TOUR with MEN in the INDUSTRY

▸ **William C. Lagos** has joined William J. Carey as landman in Dallas. Lagos was most recently associated with the Union Oil Company of California in the Denver division offices.

W. C. Lagos

E. F. Blake

▸ **Elmer F. Blake** has rejoined Southern Geophysical Company as vice president in charge of Rocky Mountain operations with headquarters in Denver. He was previously with Southern for five years before resigning in 1954 to enter business for himself as consulting geophysicist, seismic and core drilling contractor of Denver and Grand Junction, Colorado.

▸ **Robert E. Rettger** has been named assistant division chief geologist-technical and **Wallace Ralston** assistant division chief geologist-operational for Sun Oil Company's Southwest production division. In their new posts, Ralston and Rettger will assist division chief geologist **Francis E. Heath** in planning and administering work of the geological department throughout the Southwest division.

▸ **Rex L. Hardaway** has been appointed a petroleum engineer for Slick Recovery Corporation, San Antonio, Texas. He will be responsible for the production operations, principally in South Texas. He formerly was with Delhi-Taylor Oil Company serving as district engineer in McAllen, Texas.

▸ Heritage Petroleum Corporation has been organized for the purpose of purchasing oil and gas production throughout the Southwest. **C. C. Harter Jr.** will serve as president and **Clinton Davidson** as one of the principal officers. Harter was formerly executive vice president of Oil & Gas Property Management, Inc. Davidson serves as general partner, officer or director in many companies.

▸ Sun Oil Company's Canadian production division has announced four new appointments affecting the land department in the Calgary and Regina offices, and one in the geological department. **A. M. Balfour,** formerly district landman in Regina, Saskatchewan, becomes regional landman in Calgary. **G. A. Raymond,** formerly Southern Alberta district landman, replaces Balfour as district landman in Regina. **R. D. Jones,** formerly assistant to the district landman in Regina, transfers to Calgary as Southern Alberta district landman. **V. E. Trudel,** already stationed in Regina, succeeds Jones as assistant to the district landman there. In the geological department, **William H. Tisdall** of the Calgary office now is district geologist in charge of northeastern British Columbia, northwestern Alberta, and the foothills of Alberta.

▸ Kerr-McGee Oil Industries, Inc., has announced a number of changes in the exploration department. **Harold J. Kleen,** formerly chief geologist, assumes the newly created position of manager of land, geological and geophysical departments. **Walter Marlin** becomes **J. C. Finleys'** vice president in charge of exploration, special assistant. **Ralph H. McVay** becomes superintendent of the land department and **C. R. Washburn,** assistant superintendent of the land department. **L. W. Curtis** was named regional geological manager in charge of the central division, the Rocky Mountain division, and the Panhandle district. **J. A. Masters** is regional geological manager in charge of the Southern division, the West Texas-New Mexico division and the Canadian division. **D. L. Amonett** becomes chief geophysicist. Replacing Masters as divisional geological manager of the Canadian division is **R. L. Duncan.** Other divisional geological managers are **R. B. Capps,** Southern division, and **P. R. Becker,** West Texas-New Mexico division. **S. G. Hardison** is district geologist of the Panhandle district; **D. L. Brown** and **J. C. Meyer** are district geologists of the Rocky Mountain division.

▸ **Earl Gordon Griffith,** formerly district exploration manager for the Denver district of Tennessee Gas Transmission Company, has joined Wm. Ross Cabeen and Associates, Denver, Colorado.

▸ **Harry Freeman** of the engineering department of Murphy Corporation in El Dorado, Arkansas, has been transferred and promoted to the position of production foreman in the company's division office in Billings, Montana. **Wade Moore** who has been acting division geologist of the company's Billings, Montana, division, has been promoted to the position of division geologist.

▸ **Russell E. Hayward** has been appointed to the post of chief geologist for Canadian operations, with offices in Calgary, of Alex W. McCoy Associates, Inc., petroleum consultants. He formerly was the assistant zone exploration manager for Gulf Oil Corporation.

▸ **John H. Kime,** superintendent of the production and storage department of United Fuel Gas Company, has joined Preston Oil Company as vice president. Both United Fuel and Preston Oil are operating companies of Columbia Gas System.

J. H. Kime

R. F. Faull

▸ **R. F. Faull,** laboratory director, La Habra Laboratory of California Research Corporation, has been appointed vice president of oil field research for the Standard Oil Company of California subsidiary. He succeeds **J. H. Thacher** who recently was elected president of Iran-California Oil Company. **Alex Hildebrand,** manager of producing research at the La Habra Laboratory, has been named Faull's successor. In other administrative changes, **N. A. Riley** becomes assistant laboratory director and manager of exploration research and **R. E. Loeck** becomes manager of producing research both at La Habra Laboratory.

▸ Cosden Petroleum Corporation has announced the association of **Billy Joe Moore,** formerly division landman for Texas Pacific, as landman and manager of its Midland, Texas, exploration office. He will head the Permian Basin land division.

B. J. Moore

W. C. Sutherland Jr.

▸ **W. C. (Dub) Sutherland Jr.** has joined Cable Engineering, petroleum engineering firm of Wichita Falls, Texas. He was previously with Continental Oil Company as field supervisor of drilling, completion, and workover at Ardmore and Oklahoma City, Oklahoma; New Mexico, and Odessa, Texas.

▸ **E. W. Rogers** has been appointed field superintendent of British-American Oil Producing Company's Southern Oklahoma fields. He was formerly district engineer at Oklahoma City. Concurrent with the promotion of Rogers came the promotion of **John C. Thrash** who was appointed district engineer for the central district replacing Rogers. He was formerly senior staff engineer in the company's head offices in Dallas.

▸ **John J. Redfern Jr.,** Midland, Texas, an independent oil operator of West Texas and New Mexico, has been elected to a 4-year term trustee of Rensselaer Polytechnic Institute, Troy, N. Y.

▸ **J. Langford Shaw,** Oklahoma oil producer from Ada, Oklahoma, has anounced the opening of offices in Dallas. He has been active in land-leasing and drilling in Oklahoma, Texas, and the southeastern states for the past thirty years. In his new offices, Shaw will be associated with **Charles A. Shaw,** who recently resigned as senior geologist in charge of the Mid-Continent, West Texas, Rocky Mountain, and Canadian areas for Union Oil and Gas, Houston.

▸ **Charles B. Officer Jr.,** has joined Gravity Meter Exploration Company in Houston. He also will participate in activities of two other firms affiliated with GMX Corporation, minerals consultants, and Geophysical Associates International. Most recently he was an associate professor of geology at Rice Institute.

▸ **Floyd Green,** who has been conservation attorney for the Corporation Commission since July 1939, has resigned because of ill health.

▸ **R. E. Clarke** has been appointed to the newly created position of manager, natural gas utilization, of Standard Oil Company of California. He was formerly manager of the gas organization in the producing department.

▸ **C. B. "Pat" Caruthers,** staff engineer in the Fort Worth division offices, has been named field superintendent at Pan American Petroleum Corporation's Yates area, headquartered at Iraan, Texas. He succeeds **F. H. Clements,** who has been transferred to an assignment in Pan American's Venezeulan operations.

PARKERSBURG bolted steel tanks

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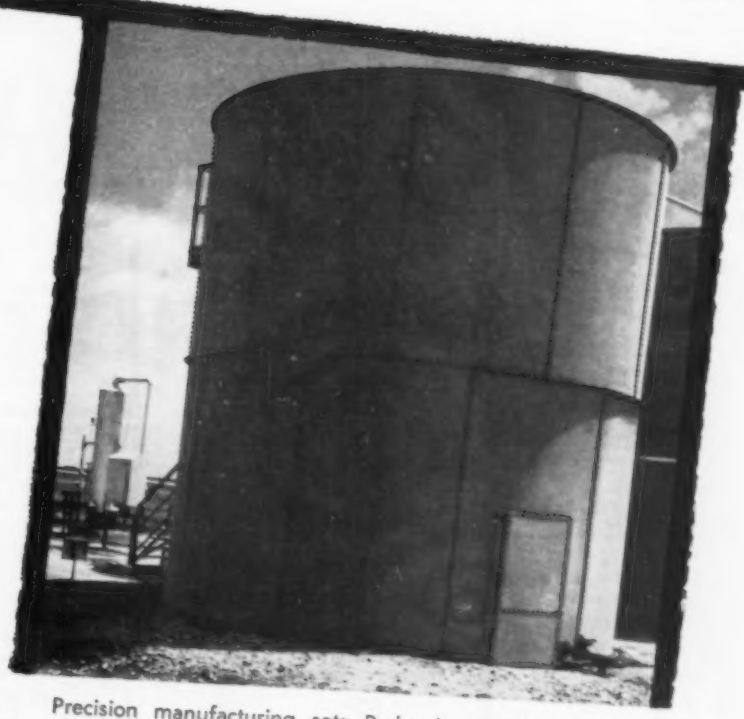
low cost...



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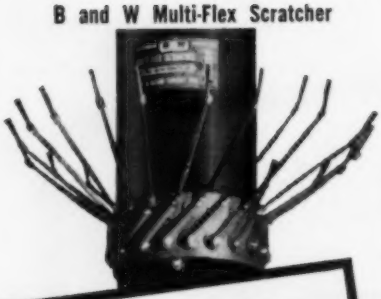

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Running Tour

▸ **Bert C. Timm** has been named chief geologist for Sunray Mid-Continent Oil Company. **Thomas A. Clote,** formerly division geologist for Sunray's West Texas-New Mexico territory, has been named division geologist for the Oklahoma division, the area previously handled by Timm. **Walter J. Slagle,** district geologist located in Oklahoma City, has been promoted to division geologist for the West Texas-Southeast New Mexico area, replacing Clote. He has moved to Tulsa on his new assignment. **Russell J. Ford,** formerly senior geologist in the Oklahoma City office, has been promoted to district geologist, the post previously held by Slagle. Chief geophysicist for the company is **Stefan Von Croy.** Two other division geologists are also headquartered in the Tulsa home offices: They are **Sherril A. Shannon,** who heads Sunray's geological operations in Kansas, Colorado, Utah, Montana, North Dakota and Wyoming; **Watson Caldwell,** who directs geological activities in South and East Texas, Louisiana, Arkansas and Mississippi.

▸ **Jed B. Maebius** has been appointed to the newly created position of senior geologist for domestic exploration in Tidewater Oil Company's headquarters exploration department. For the past two years he has served as a consulting geologist in Tulsa.

J. B. Maebius

Robert Dyk

Robert Dyk has been appointed to fill the newly created post of chief geophysicist. He came to Tidewater from Geophysical Service, Inc., Denver, where he was manager of the concern's Mid-Continent division.

▸ **Richard Robert Anderson** has been appointed administrative assistant of Sun Oil Company's production department. Anderson moves to Sun's general offices in Philadelphia from the Gulf Coast division where he has been assistant regional superintendent at Lafayette, Louisiana. In his new post Anderson succeeds **Ted C. Stauffer,** who recently was named director of Sun Oil's foreign production operations.

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STANDARD and LIGHTWEIGHT
ALUMIRON COUPLINGS
(Made in Aluminum or Malleable Iron)
For Grooved End Pipe

● Think back—remember the effort required to make and complete pipeline joints? Now you can do it an easier way with these two-bolt malleable iron Couplings. Pipeline progress dictated the design of Alumiron Couplings making them the simple, quick, positive, low cost way to join grooved-end steel, aluminum, cast and wrought iron and spiral pipe.

● Alumiron speedily joins grooved-end pipe by the mere tightening of two bolts which run through the coupling halves. The Buna N or oil resistant Neoprene gasket inside the coupling halves firmly and evenly grips the pipe ends making a leak-proof seal which increases as pipeline pressure mounts. This flexible Coupling permits the line to "come and go" with rough and uneven terrain. Component parts are interchangeable with other grooved-end couplings.

● Standard Series to 1,000 PSI working pressure in sizes 1" through 8". Lightweight Series to 500 PSI working pressure in sizes 2", 2½", 3", 4".

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FIG. 91

Simplicity and compactness, for ease of installation and neatness of hook-up, are incorporated into the Larkin Casing Head (2000 psi test, 1000 psi working pressure.) It is designed to provide a safe and economical means of suspending and packing off casing strings. This head has been tested to support 225,000 lbs., equivalent to 5600' of 7", 20-lb. casing with a safety factor of 2.

TYPE L

A new member of the Larkin Well Head line, the Type L Tubing Head fills a need in low pressure areas where economy may be effected with complete safety. It is forged steel construction, full opening, 2000 lb. psi, top of body threaded 7" API to accommodate control equipment, hinged three-segment slips, 2" or 3" side outlets.

HEAD OF THEIR CLASS for medium pressure wells

TYPE R

The Larkin Type R. Tubing Head is a conversion from the Type SR Head. This ease of conversion makes it possible to use the same stripper adapter and Neoprene stripper when working on any well equipped with a Larkin Tubing Head.

TYPE SR

The Larkin Type SR Tubing Head is a slip suspension head, equipped with a Neoprene Stripper which serves as a blow-out preventer and oil saver while tubing is being pulled or run. It is very suitable where higher pressures might be encountered.

For detailed information on these and other Larkin Tubing and Casing Heads, please refer to your Larkin Catalog or talk to your Larkin Representative. All Larkin Equipment is available through your supply store.

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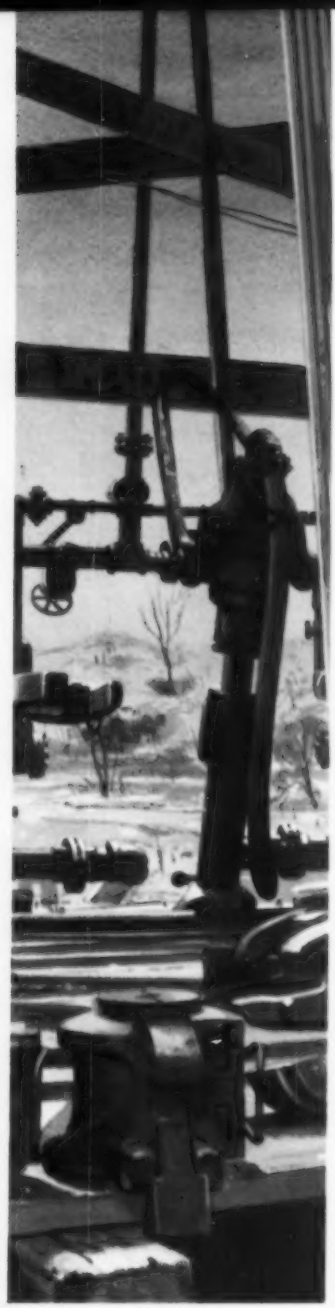


Reed introduced the *first* rotary rock bit equipped with four cutters which rolled on bottom in 1917, and by 1919 this original cross roller bit had set new records for fast and economical drilling in rock. Reed's popular cross roller rock bits were used extensively in the fast development of Gulf Coast fields following World War I.

By 1919 much of the drilling activity was devoted to extending existing fields and developing new commercial horizons within these fields. Some of the fields with extensive drilling operations during this period were West Columbia in Brazoria County, Goosecreek and Humble in Harris County, Barbers Hill in Chambers County, Blue Ridge in Ft. Bend County, and Hull in Liberty County.

Also in 1919, the small but ambitious partnership that had produced the first successful cross roller rock bit became a corporation. From their first plant in a small 30x40-foot rented building on Harrisburg Boulevard, Reed purchased and moved to a 28-acre tract on Navigation Boulevard which is covered today with the most modern oil tool research and manufacturing facilities. Just as Reed cross roller rock bits were synonomous with drilling progress in 1919 . . . Reed Y Bits lead in drilling efficiency *today* with increased penetration rates . . . increased footage per bit . . . and increased dependability.

BEST IN 1919 . . .

The Original Reed Cross Roller Rock Bit

BEST TODAY . . .

REED Y BIT

FREE REPRINT

This is the first of a series of four paintings on the history of famous oil fields. To obtain your FREE 17 x 14" full color prints suitable for framing of the entire series, send your request to Department H, Reed Roller Bit Company.

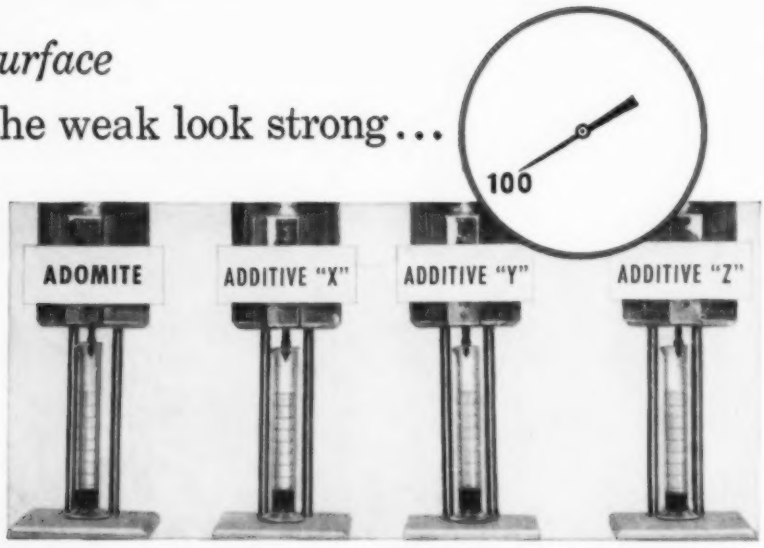
GULF COAST · 1919 Rig floor scene in the Goose-creek, Harris County, field. Note the exposed chain drive to the rotary, single band drawworks and wooden derrick.

REED ROLLER BIT COMPANY

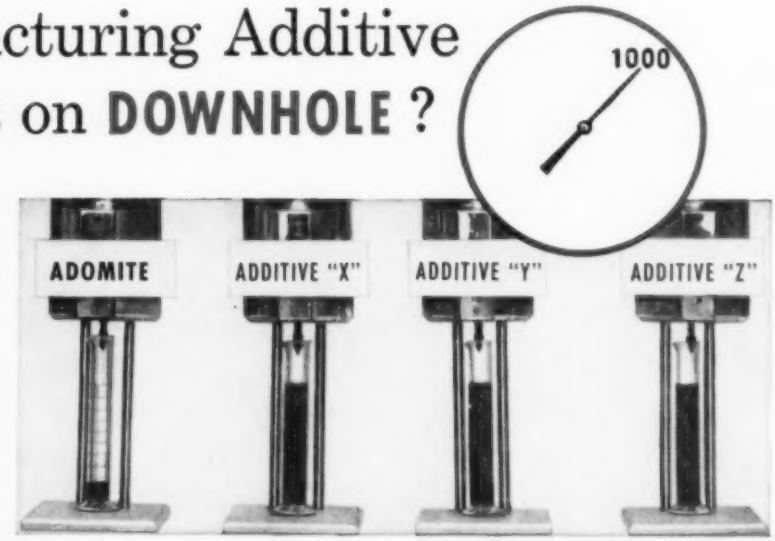
HOUSTON 1, TEXAS

On the surface

even the weak look strong...



but which Fracturing Additive can you count on **DOWNHOLE**?



Some fluid loss control additives act impressively at surface conditions of low pressure and room temperature. But downhole, they let you down . . . with fluid loss becoming so high that their effectiveness is lost. That's what distinguishes Adomite from other fluid loss control additives. You can count on Adomite for *deep-down* effectiveness.

What's the secret of Adomite's *deep-down* effectiveness? Adomite, when mixed with oil, disintegrates into millions of tiny particles. These particles seal the face of the formation and keep the fracturing fluid from filtering in. Temporarily sealing the formation, Adomite particles do not plug it.

Where do other additives fail? These likewise contain sealing particles, but tend to soften or dissolve as temperatures increase. Consequently, fluid loss control is greatly reduced.

To be sure of least fluid loss, tell your service company to fracture with Adomite.

	Fluid Loss at Surface Conditions— 100 psi,* 75°F., cc/30 min.	Fluid Loss at Bottom Hole Conditions— 1000 psi, 150°F., cc/30 min.
Adomite plus crude oil	**2.2**	**22.0**
Additive X plus crude oil	**37.8**	**Infinite**
Additive Y plus crude oil	**8.5**	**Infinite**
Additive Z plus crude oil	**13.0**	**295 (1 min., 50 sec.)**

* Standard API Code 29 Test

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Adomite®

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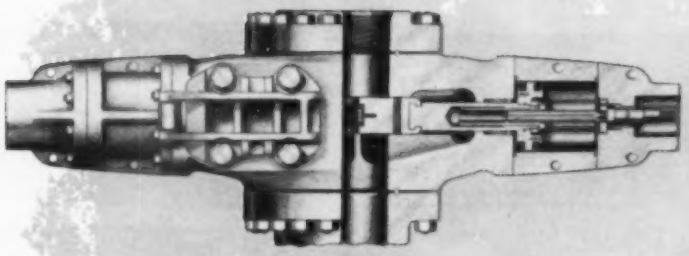
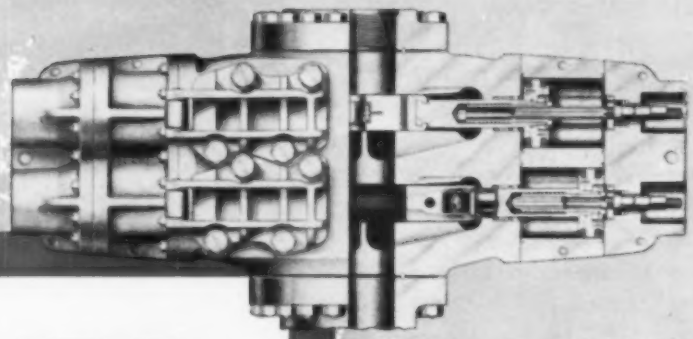


Here's the Shaffer Hydraulic SINGLE Cellar Control Gate with *Non-Rising* Locking Shafts for maximum compactness. You can use this Gate either alone, in assemblies of two or more, or in a combination hook-up with the Double Gate shown below.



And here's the Shaffer Hydraulic DOUBLE Cellar Control Gate with *Non-Rising* Locking Shafts—the gate that unitizes *two* ram compartments into *one* compact body. Note how both the Single and Double designs have the same unique *side-opening* doors for unequalled convenience in changing rams!

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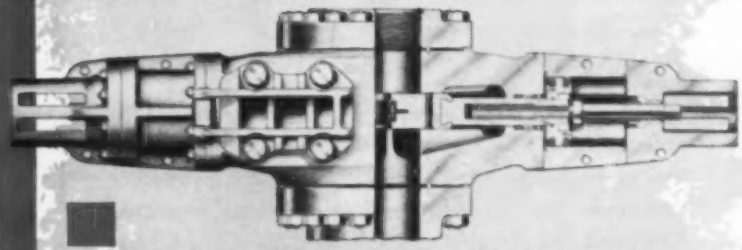
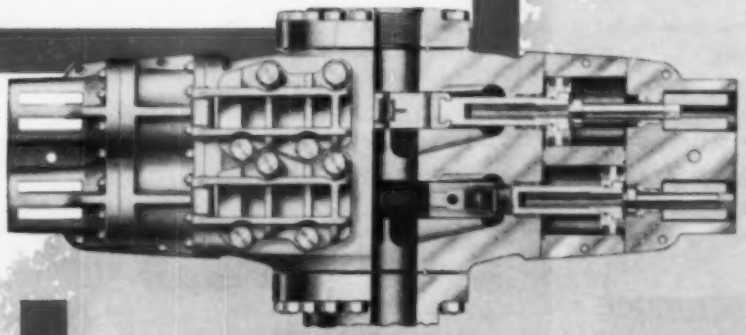
ADAPTS CELLAR CONTROL GATES TO FIT YOUR NEEDS!

Although Shaffer Hydraulic Gates incorporate the finest basic design in the industry, the design is still flexible enough to give you a choice of operating features to meet your particular *preferences.*

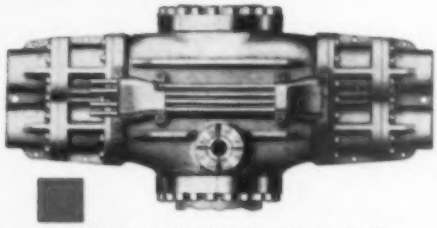
For example...



And here's the Shaffer Hydraulic SINGLE Cellar Control Gate with *Rising* Locking Shafts for maximum ease in checking ram position. It has the same advanced design as the units above—and most parts are interchangeable, size for size, thus simplifying inventory requirements.



And if you want a DOUBLE Gate with *Rising* Locking Shafts, Shaffer has that, too. All designs are Completely Enclosed...all feature Direct Drive without yokes or complicated connections between pistons and rams.



And here's the back view of the Double Gates. No matter which of the four Gate designs you select, the hydraulic manifolding is as simple and clutter-free as shown here—and they can be had with built-in outlets to eliminate spools in the hook-up.

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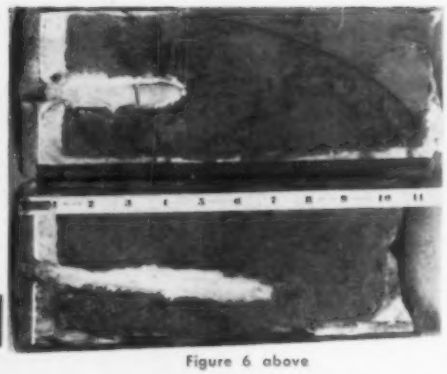

Figure 6 above

SEE PROOF (Figure 2, from one Bulletin) of shooting tests into two 72-hour cured cement targets—**correlated by coring tests** as equivalent to the **softer** of actual Gulf Coast and Louisiana producing formations. See how the Bullet (top test) shot completely through its 15" target, while the Jet penetrated to only 11⅞". For such formations, obviously, more-costly Jet charges would be a waste of your money!

SEE PROOF (Figure 3) of tests in two 5-day neat cement targets—likewise **correlated by coring tests** as equivalent to the **harder** Gulf Coast and Louisiana producing formations. See how the Bullet (lower test) penetrated 12⅛", and the Jet only 11⅜". For such formations, less-costly Bullets would again save you money.

SEE PROOF (Figure 6) in very dense and hard formations such as the Berea Sandstone actually used for these two tests, how the Jet (lower test) penetrated 6¾" and the Bullet only 4¼". BUT also see in Bulletin that despite the difference in these penetration depths, Flow Index tests indicated that **production rates** from such Bullet and Jet perforations are almost identical. So, here again, Bullets would save you money!

SEE PROOF in the Bulletins, too, that for certain other perforating conditions and types of formations, Jets are definitely superior to Bullets. That's why you need these two PGAC Bulletins. Write today for them.

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Remember, PGAC offers both Bullet and Jet Perforating—both the world's most powerful available. And PGAC wants to help you cut costs when possible!

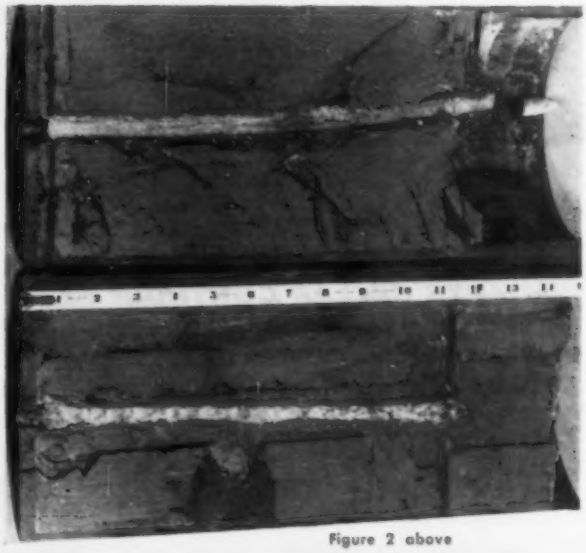

Figure 2 above

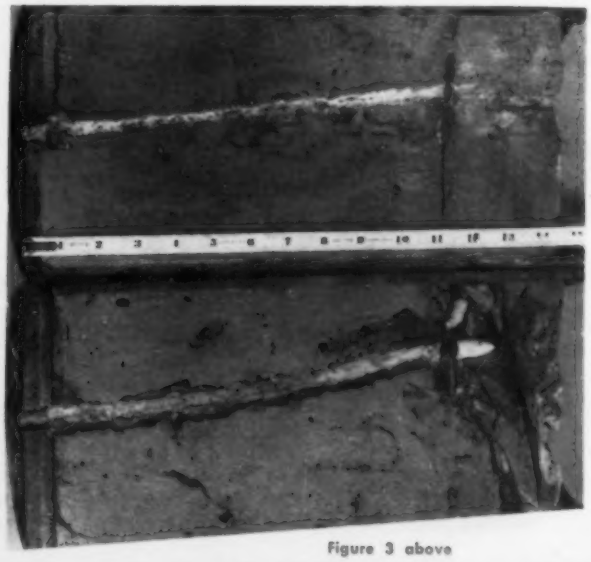

Figure 3 above

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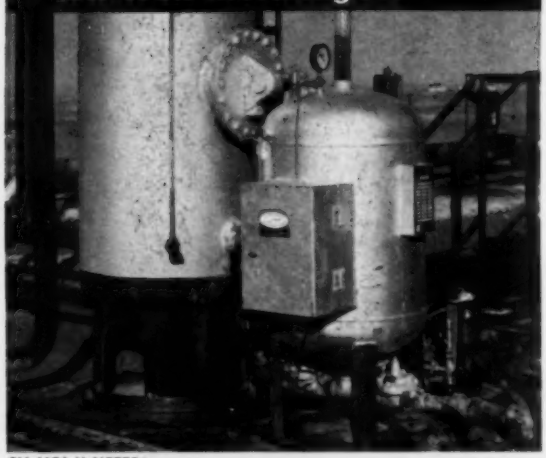

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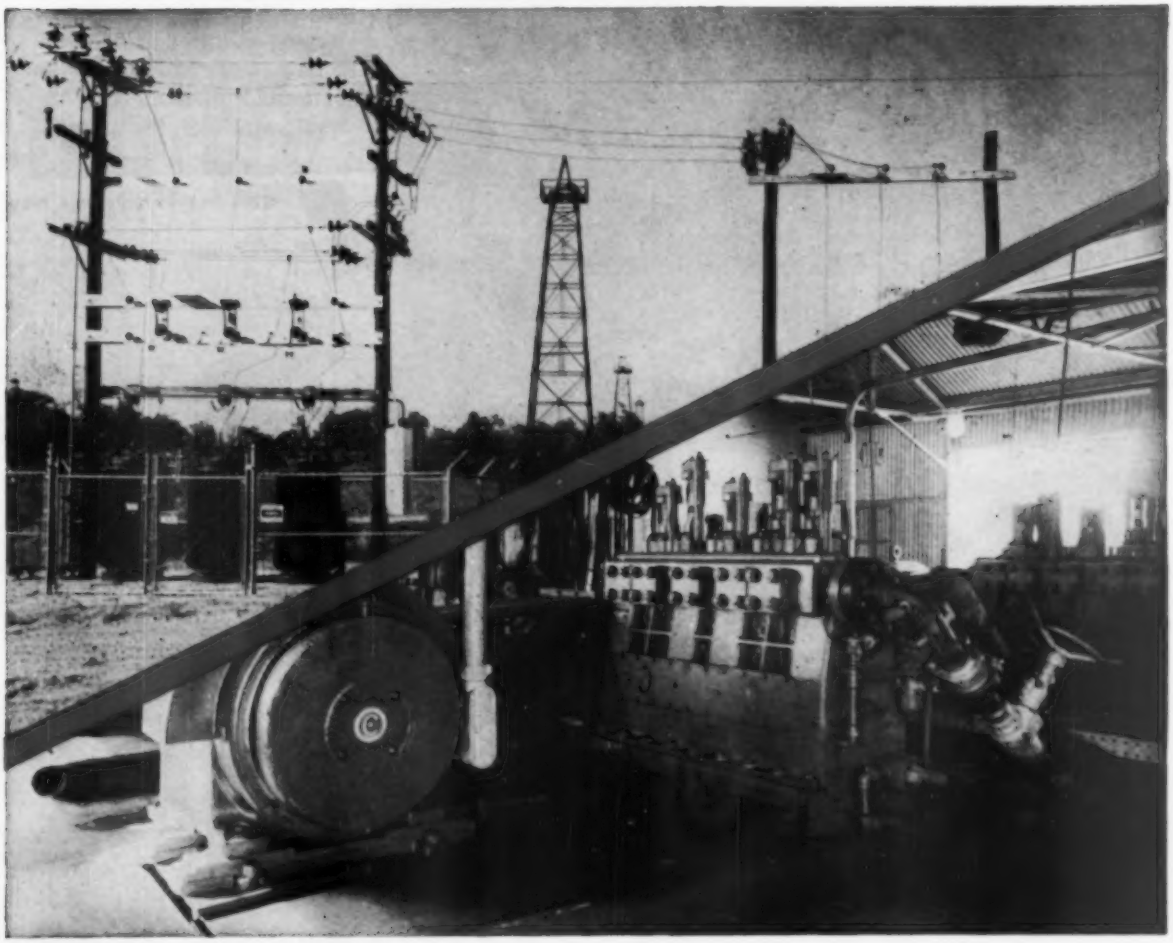

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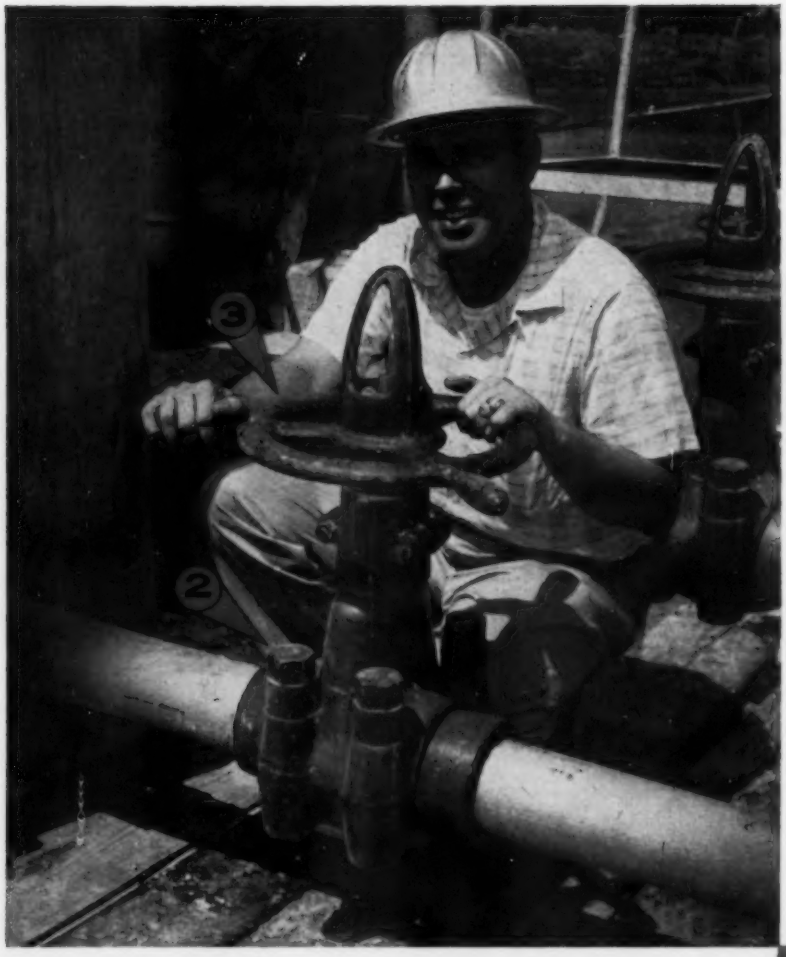

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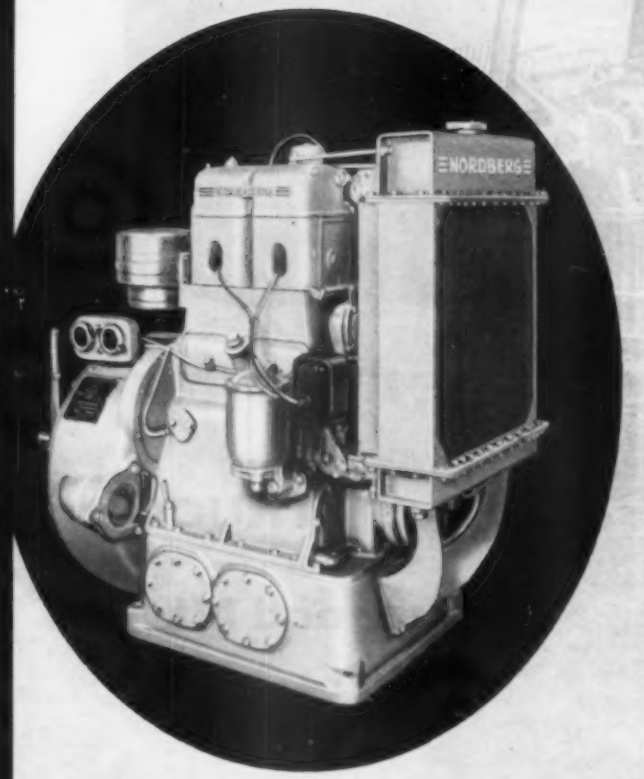

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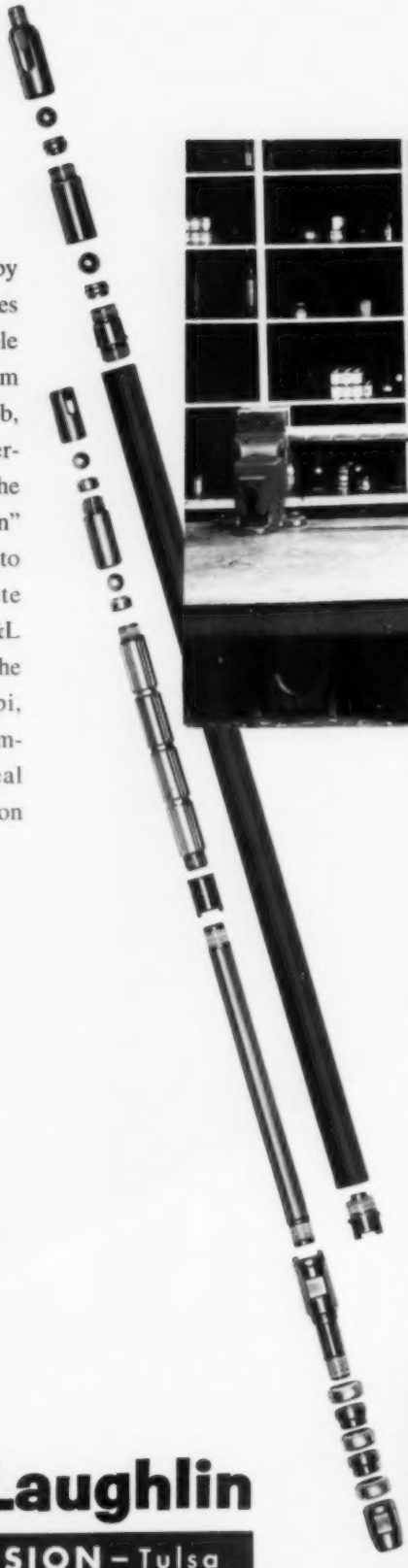

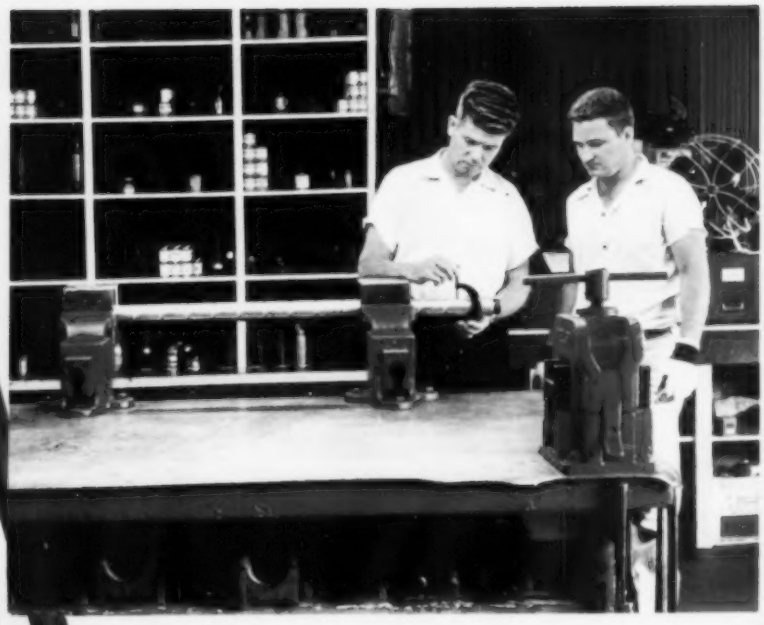

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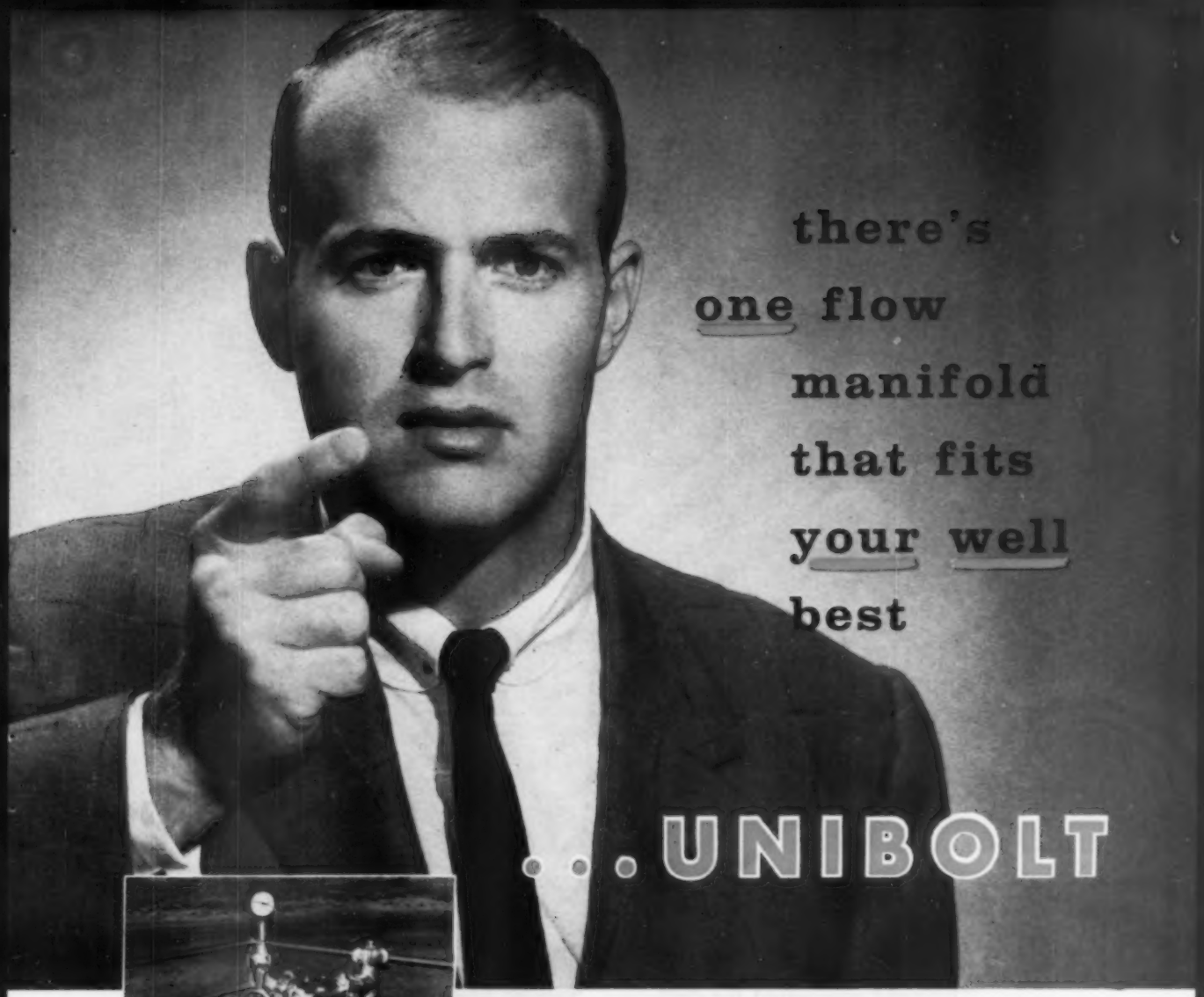

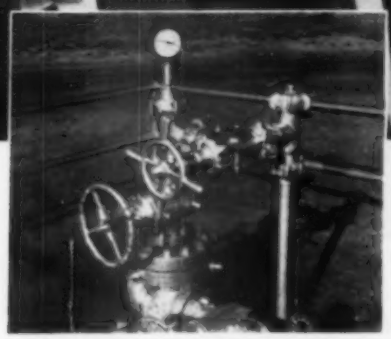

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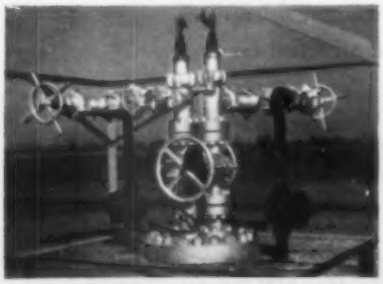

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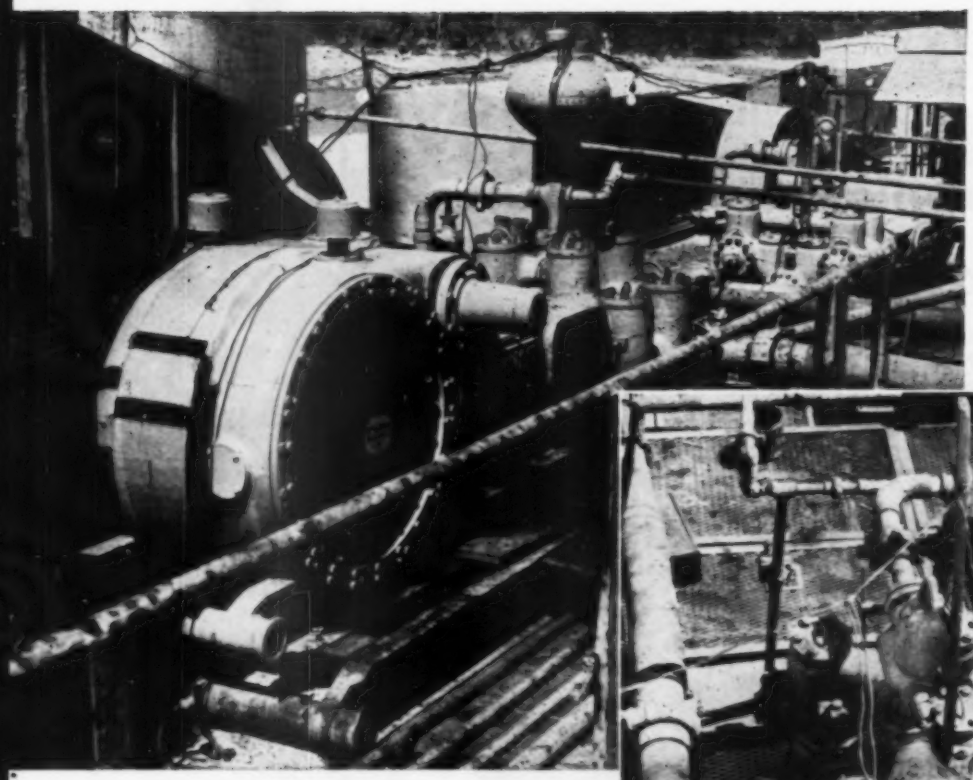

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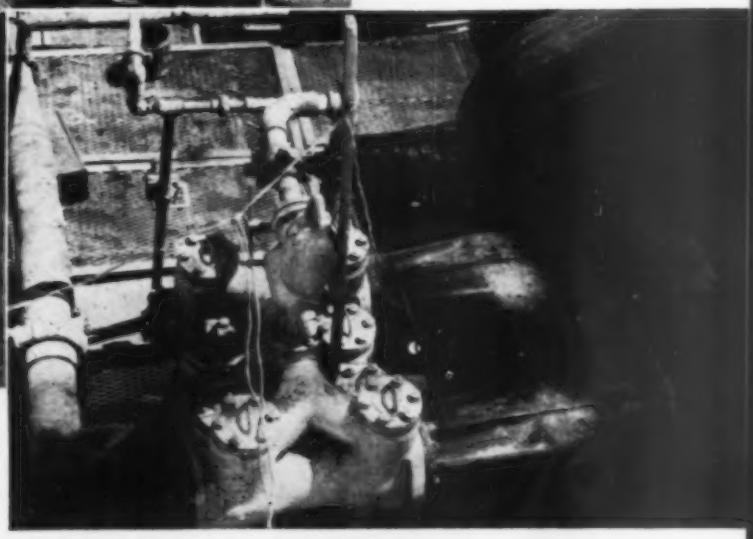

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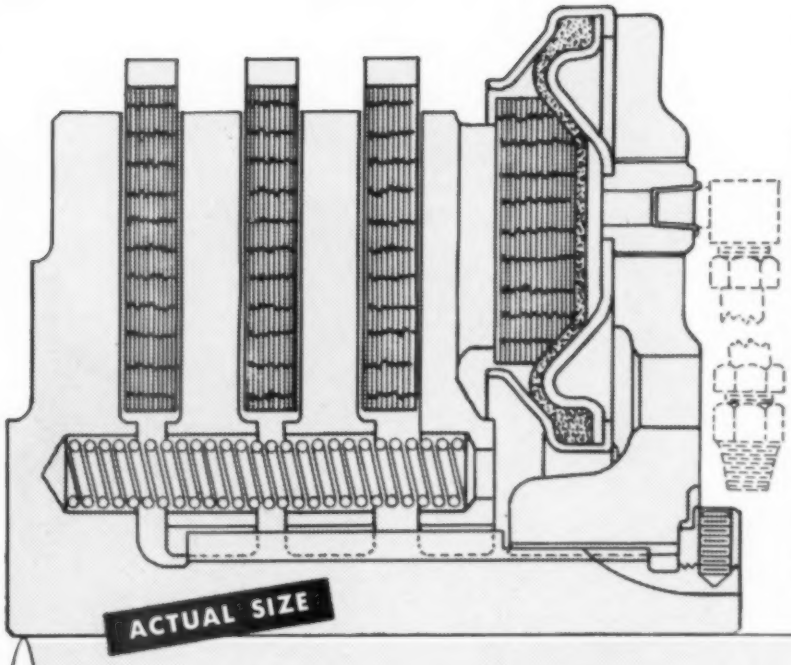
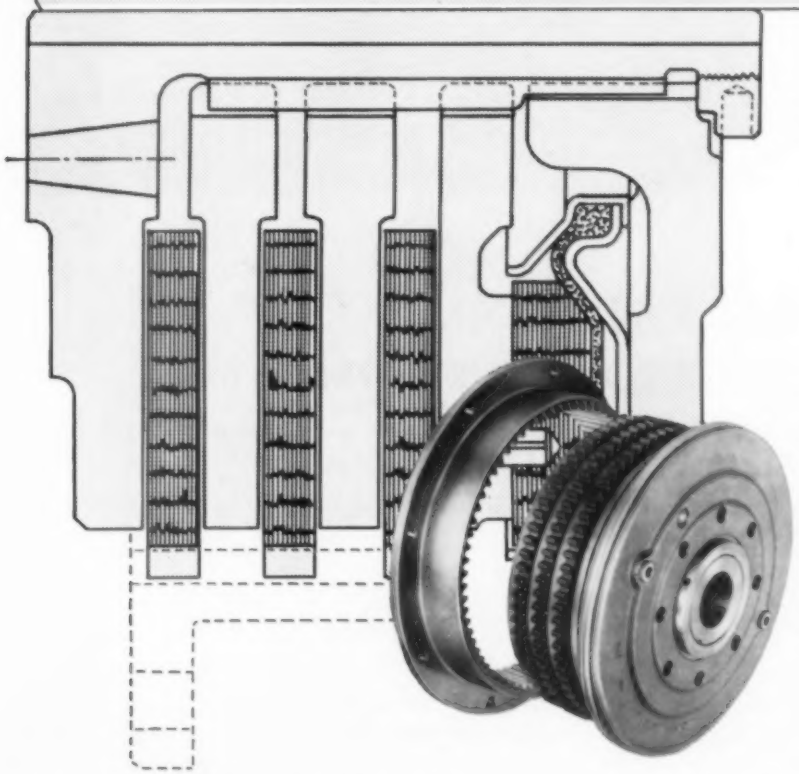


- New design permits highest capacity at up to 40% less cost than comparable remote controlled air clutches!
- Available in sizes 8, 10 and 11½ inches . . . in triple-plate, double-plate and single-plate construction . . . with maximum torque capacity of 3503 pound-feet.
- Exclusive cartridge-type diaphragm of long-lasting neoprene reinforced with nylon . . . eliminates leakage and provides long life.
- Provides constant torque capacity without adjustment . . . self-compensating for wear.
- Compact and rugged . . . with clutch mass properly distributed relative to friction area, providing long life on high energy loads.
- Narrow width permits replacement of old-style drum or band clutches.
- Suitable for air systems up to 130 pounds per square inch.

New LOW COST high capacity Twin Disc Air Clutches



The new Twin Disc 8, 10 and 11½-inch PO Air Clutches are adaptable wherever the convenience of remote air control is desired. They are currently being used by leading manufacturers of oilfield equipment. They have proved excellent as master clutches, rotary clutches and high and low-speed clutches on drawworks.

The three new sizes extend the time-test, job-proved line of PO Air Clutches from 8 to 36 inches . . . in torque capacities to 126,600 pound-feet.

Specify Twin Disc PO Air Clutches in your next piece of oilfield equipment . . . see for yourself how they lend themselves to convenient, economical remote control. Write Twin Disc Clutch Company, Racine, Wisconsin, for full details.

TWIN DISC

TWIN DISC

Friction Clutches and Fluid Drives

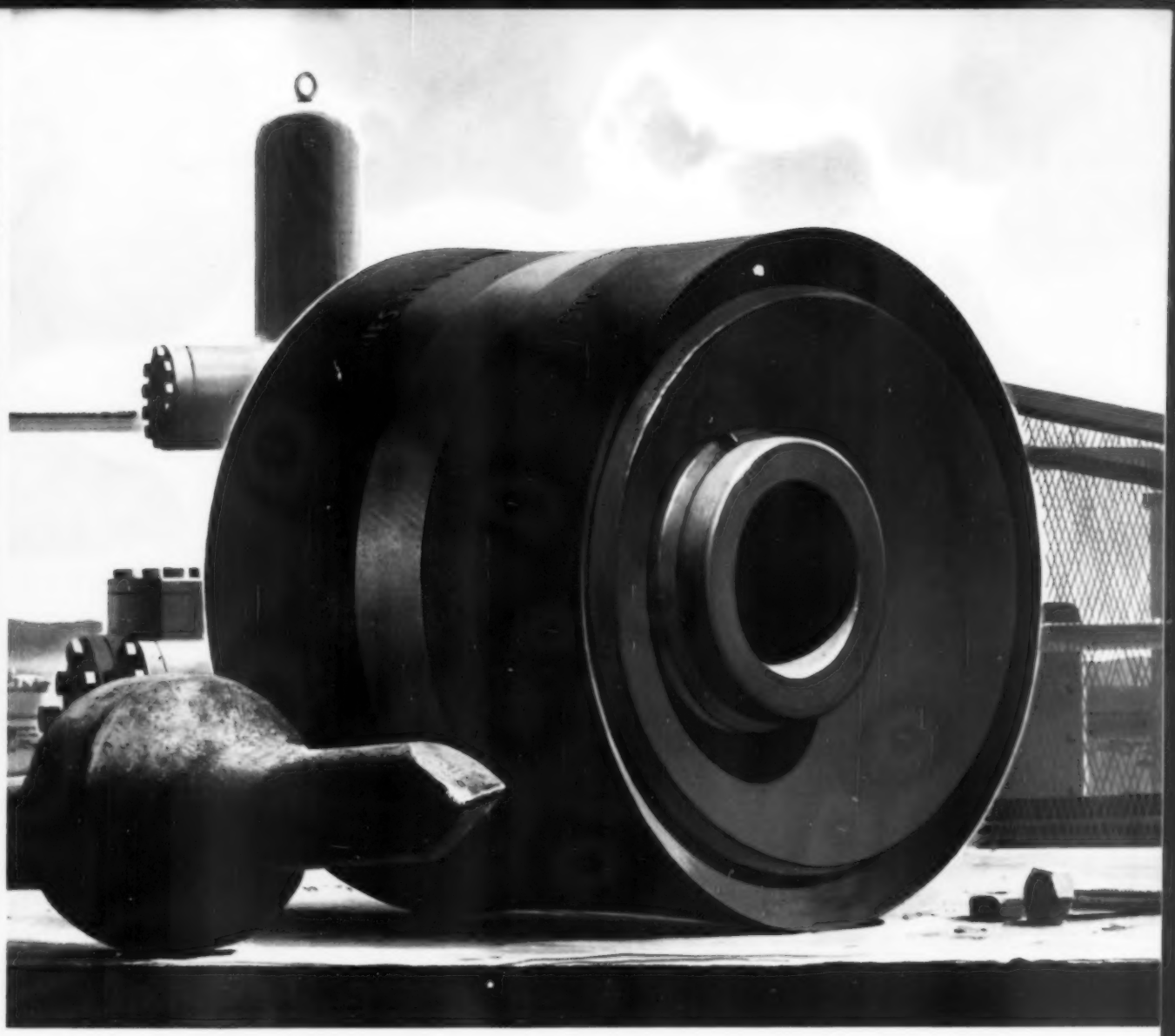
There's a lot more difference in these **MISSION PISTONS** than just ten years!

Although these two Mission Pistons look a lot alike, the 1957 model at the left will give much better service than the 1947 model at the right.

With the 1957 model, you can take advantage of far higher pump pressures than you could when using any other pistons — including Mission Pistons of ten years ago.

Or, if you don't require high pressures, you can get far longer service life than before.

Why? There are many good reasons! In the past ten years for example, *27 improvements*



have been incorporated into Mission Pistons.

Most of these improvements, such as advances in piston rubber compounds, can't be seen, but they mean that today's Mission Pistons are giving excellent service under jet drilling conditions that would have been considered impossible only ten years ago.

In addition to the changes actually made, Mission Engineers have conducted 371 *test pump laboratory and field tests on piston rubbers alone in just the last three years.* That's an average of over 120 tests per year.

This kind of research means lower costs, less down time, better slush pump performance and faster drilling for you. It is an important reason why more Mission Pistons continue to be used than all other makes combined. You can get Mission Pistons and Mission Piston Rubbers through supply stores everywhere.

PESA

Nothing but the finest will bear the name of

MISSION MANUFACTURING CO

MISSION MANUFACTURING CO. • P. O. Box 4209 • Houston, Texas • Cable Address—"Missco" • Export Office: 30 Rockefeller Plaza, New York
In The United Kingdom: MISSION MANUFACTURING CO., LTD. • 17 Hanover Square • London, W. 1, England • Cable Address—"Missoman"

SLUSH PUMP VALVES - PISTONS - VALVE SEAT PULLERS - LINERS - PISTON RODS - VALVE SPRINGS - GLAND PACKINGS - - SLIPS - SWABS - PLUG VALVES - CENTRIFUGAL PUMPS

MARVEL INVERSE OILER–

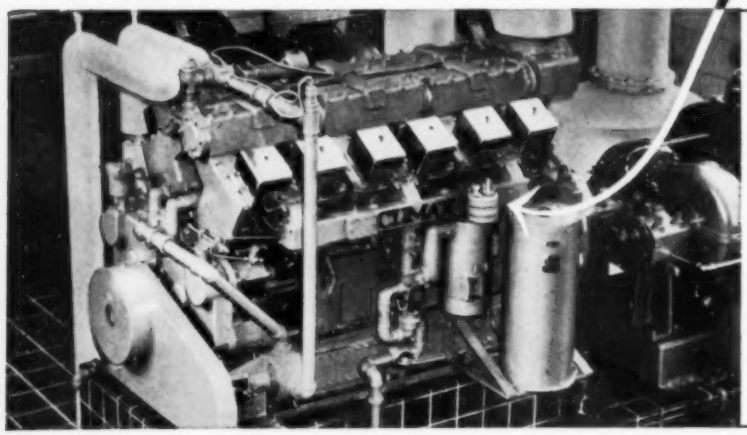
Vital Part of World's Finest Engines

Engine manufacturers think so highly of the Marvel Inverse Oiler they have incorporated it is a vital unit in their engines' lubrication systems.

They have found that engines, equipped with Marvel Inverse Oilers, can be depended upon to give quick acceleration to save trip time . . . keep operating costs to a minimum . . . guarantee hours of continuous performance . . . keep "down-time" low by extending periods between overhauls.

The famous Climax Engines, one of which is pictured below, is an example. A truly fine performer, it is equipped with a Marvel Inverse Oiler for Marvel Mystery Oil—finest performing lubricant of all.

The Marvel Inverse Oiler feeds Marvel Mystery Oil in exact proportion to engine speed and load . . . properly lubricating valves and guides, preventing wear and sticking. Keeps upper piston rings free in their grooves . . . retards ring flutter . . . and cushions ring pounding which can result in ring breakages. Remember, it is the *oil* which must do these things and only Marvel Mystery Oil is blended for this purpose and for this oiler.



The Marvel Inverse Oiler

is an integral part of the Climax 12 cylinder, 171 H.P., 600 RPM GAS ENGINE. Operating off the intake manifold, this completely automatic Oiler feeds Marvel Mystery Oil exactly in proportion to engine loads . . . gives direct protection to the all-important upper cylinder areas.

This Chart shows the proper setting for constant load engines

BRAKE H. P. AT BELT	NAT. GAS CU. FT. PER HOUR	BUTANE GALLONS PER HOUR	GASOLINE GALLONS PER HOUR	M. M. OIL DROPS PER MIN.	M. M. OIL HOURS PER QUART
10	115.	1.07	1.12	4	228
15	172.5	1.60	1.68	6	152
20	230.	2.14	2.24	8	114
25	287.5	2.67	2.80	10	91
30	345.	3.21	3.36	12	76
35	402.5	3.74	3.92	14	65
40	460.	4.28	4.48	16	57
45	517.5	4.81	5.04	18	50
50	575.	5.35	5.60	20	45
60	690.	6.42	6.72	24	38
70	805.	7.49	7.84	28	32
80	920.	8.56	8.96	32	28
90	1035.	9.63	10.08	36	25
100	1150.	10.70	11.20	40	22
120	1380.	12.84	13.44	48	19
140	1610.	14.98	15.68	56	17
160	1840.	17.12	17.92	64	14
180	2070.	19.26	20.16	72	12
200	2300.	21.40	22.40	80	11
225	2587.5	24.00	25.20	90	10
250	2875.	26.75	28.00	100	9
275	3162.5	29.42	31.10	110	8
300	3450.	32.10	33.60	120	7

Chart shows total oil consumption

EXAMPLE:—If you use 805 cu. ft. of dry gas, 7.49 gallons of butane or 7.84 gallons of gasoline, your H.P. is about 70, so adjust oiler to feed 28 drops per minute. You will then receive about 32 hours per quart of MARVEL MYSTERY OIL.

If engine load increases after setting for normal load, oiler will automatically increase its feed, decreasing when load is lessened.

To determine drop count per oiler when more than one is used on an engine—divide recommended drop count by number of oilers.

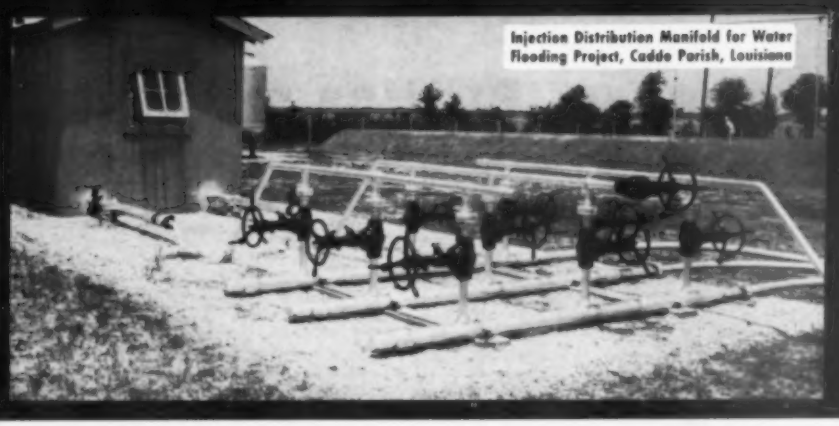
NOTE: Guarantee on oiler is void if any other oil than MARVEL MYSTERY OIL is used. Some *engines* also carry this guarantee policy.

Available in Canada through Radiator Specialty Company of Canada Ltd., Toronto 2, Ontario, Canada

EMEROL MFG. CO.

242 West 69th Street New York 23, N. Y.

Injection Well for Water Flooding Project, Caddo Parish, Louisiana



Injection Distribution Manifold for Water Flooding Project, Caddo Parish, Louisiana

WATER FLOODING WITH ORBIT FORGED STEEL VALVES

FOR LOW, MEDIUM OR HIGH PRESSURE SYSTEMS BRINE* OR FRESH WATER

ORBIT FORGED STEEL VALVES ARE WIDELY USED IN WATER FLOODING SYSTEMS— for Services such as:

Injection Wells,
Injection Water Distribution Manifolds,
Pump Discharge Lines,
Field Lines.

Sizes: 1", 1½", 2", 2½", 3" and 4". 500 lbs. thru 5000 lbs. Working Pressure, Stainless or Carbon Trim.

REASONS WHY YOU SHOULD USE ORBITS IN WATER FLOODING SYSTEMS:

1. Non-lubricated friction-free shut-off.
2. Trouble-free—Orbit valves will continue to operate easily even under the severest corrosive conditions encountered in water flooding service. Corrosion does not interfere with the opening or closing operation of Orbit valves.
3. Availability—Stocked by your local supply store.
4. Full round straight thru unrestricted opening.
5. Full range of sizes.
6. Eliminates contamination from valve lubricants.

*For Brine Services we recommend stainless trimmed Orbit valves.

ORBIT VALVE COMPANY
Tulsa, Oklahoma, Box 699, LUther 4-4761, TWX TU 923

WAREHOUSES: HOUSTON, TEXAS, 407 Velasco, CApitol 8-6623, TWX HO 115; ODESSA, TEXAS, 402 West County Road, FEderal 7-2263, TWX ODESSA TEX 8041; EDMONTON, ALBERTA, CANADA, 7119-104th Street, Phone 391-283

WEST COAST REPRESENTATIVE: Fred P. Koenig Company, Long Beach, Calif., 3815 Atlantic Avenue, GArfield 4-3834

CANADIAN REPRESENTATIVE: T. R. Pickford & Company, Ltd., Calgary, Alberta, 536 8th Avenue West, Phone 2-7371

EXPORT REPRESENTATIVE: New York 36, N. Y., 500 Fifth Ave., BRyant 9-2236

NEW Drilling and Producing Equipment

Shearing Relief Valve. Latest addition to the Cameron line is the 2-in. high pressure shear relief valve settings of 1000, 1250, 1500, 1750, 2250, 2500, 3000, 3500, 4500 and 5000 psi (number 212552-2).

Cameron shear relief valves shear a common nail to prevent damage if pressures surge beyond normal limits. Synthetic rubber piston and stainless steel liner sub and stem prevent corrosion, leaking and sticking. Also new in the Cameron line is the 2-in. 10,000 psi unit. *Cameron Iron Works, Inc.*

Circle number (1) on reply card.

Control Now Pneumatic or Electric. Long a standard in the industry, the Model 751 Magnetrol Liquid Level control is now available for either electric or pneumatic operation—or both. A newly developed Pneumtaic Pilot Mechanism—the J-1—is designed to be completely interchangeable, in the field, with the standard electric mechanism. New mechanism utilizes the same time-proved magnetic operating principle featured in all Magnetrols. Featuring all stainless construction, mechanism can be used with instrument air or well head gas without fear of corrosion. *Magnetrol Incorporated.*

Circle number (2) on reply card.

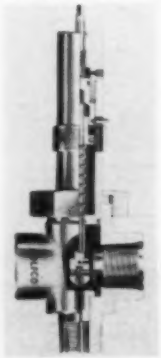
Computer Measures and Records Gas Flow. The SIE Type DRF Flow Computer is a complete system, from transducer to printed record, for computing gas flow through an orifice. Using the AGA equation, all corrections are introduced automatically and results are indicated in analog or digital form. Corrected flow information may be telemetered via telephone, wire lines or microwave, and recorded on strip charts, log sheets, or punched cards. Both flow rate and integrated volume are instantaneously available for accounting, dispatching, automatic control, and other applications. The accuracy is 1 percent of full scale under all operating conditions, and even better in normal environments. *Southwestern Industrial Electronics Company.*

Circle number (3) on reply card.

Drift Double Recorder. Totco Double Recorder is a mechanical drift indicator for controlled vertical drilling that does not depend on, or use, any liquid, chemical or electrical apparatus. By providing an accurate, double-checked record of inclination, it saves time and cuts costs. Instrument can be run in a variety of ways depending on the equipment being used and is built to stand up under every condition of well pressure and temperature. Totco record charts offer the drilling operator a permanent record of the well's progress. *Technical Oil Tool Corporation.*

Circle number (4) on reply card.

Constant Tubing Pressure Choke. Choke, C.T.P., flows and controls the well automatically within the limits of the maximum and minimum positive chokes. Gulfco's C.T.P. operates on a unique principle. To decrease the amount of fluid being produced, operator lessens the spring tension, which means that the well will flow on or near the minimum size choke until the tubing pressure declines to the set spring tension. When the spring tension is greater than the tubing pressure, the flow will increase in proportion to the decrease in tubing pressure. *Gulf Coast Machine & Supply Company.*



Circle number (5) on reply card.

Fluorescence Analysis Cabinet. Long wave ultra-violet and white light all in 1 portable "darkroom," MINERALAB, is lightweight, and may be used with or without a microscope. It is ideal for "on the spot" inspection — for oil core analysis at the rig or in the open laboratory. *Ultra-Violet Products, Inc.*

Circle number (6) on reply card.

Instrument Speeds Moisture Analysis. Schlumberger NMR high-speed moisture analyzer (Model 104) makes quantitative determinations of moisture content in a wide variety of solids. Some products that can be effectively analyzed by the Model 104 are polyethylene, geological cores, clay and fibrinogen. It carries out this analysis in from 30 sec to 4 min, as opposed to the 4 hr required by the oven or similar conventional methods. Operating on the principle of nuclear magnetic resonance (NMR), the Model 104 is both a research and production instrument. *Schlumberger Well Surveying Corporation.*

Circle number (7) on reply card.

Packaged Well Logging. The 2000-ft WIDCO Portable Electric Logger is typical of the complete line of well logging units leased (U.S. only) and sold by Well Instrument Developing Company for the logging of shot holes, core holes, strat holes, shallow production wells, etc.

Attachments are available for Gamma-Ray, Temperature, Mud Resistivity and Caliper logging, and also for the electric logging of air-drilled holes. *Well Instrument Developing Company.*

Circle number (8) on reply card.

Transistorized Counter for Exploration. A new, portable, scintillation counter, the UAC Million-Aire, has a sensitivity equivalent to 2 million counts per minute in a one mr/hr field of radiation.

Counter weighs only 12½ lb including the probe. It comes with a hermetically sealed 2 by 1¼ in. sodium iodide, thallium-activated crystal optically coupled to a 2 in. diam specially designed photomultiplier. *Universal Transistor Products Corporation.*

Circle number (9) on reply card.

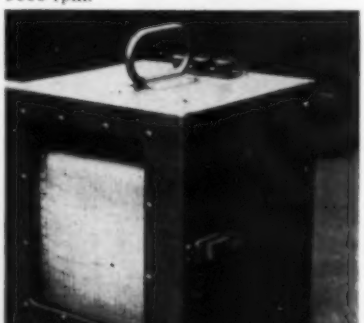
Rugged Pressure Transducer. Ability to operate accurately under vibration environments and temperature to 400 F, is offered in the new "Model H" Servonic Instruments pressure transducer. The rugged new instrument incorporates stainless steel sensing elements which permit the use of corrosive fluids in either gage or differential models. Internal resonances are eliminated, friction efforts minimized, and potentiometer life extended by the use of a special damping fluid. Case burst pressure is 7500 psi. Available in ranges from 1000 to 10,000 psi. *Servonic Instruments, Inc.*

Circle number (10) on reply card.

Variable Area Rotameter. "Safeguard" Rotameter is a "variable-area" type instrument for the accurate measurement of fluid rate of flow. It has a rigid welded steel case; a detachable easy-to-read meter scale; heavy, safety-glass windows at front and back for maximum visibility and maximum protection; metering tubes which have the same inlet and outlet OD to permit standardization of packing and end fittings and use of up to 4 tube sizes in 1 case, and is designed to use numerous rotor types for various capacities. *Schutte and Koerting Company.*

Circle number (11) on reply card.

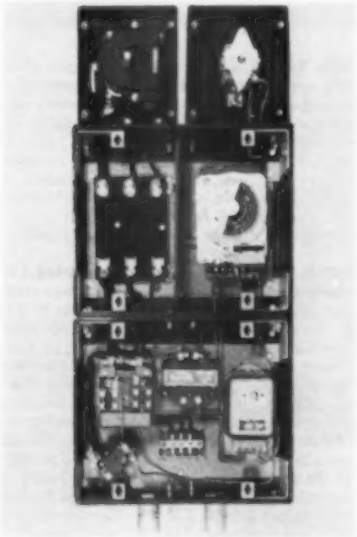
Rugged Rig Instrumentation. Martin-Decker Corporation has developed a new electric recording system capable of recording any of the following functions on a single, double, or four channel recorder: Total hook load or weight on bit; pump pressure; pump speed or volume; rotary speed; rate of penetration; torque; any pressure up to 15,000 lb and speeds up to 3000 rpm.



The pressure or rpm functions are converted to an electric signal at the rig and carried through any length of electric line to the recorder mounted in a convenient location. *Martin-Decker Corporation.*

Circle number (12) on reply card.

Controls Oil Well Pumping. American Kloeckner-Moeller No. 174 oil well pumping control has an armored plastic enclosure that is impact-proof and protects the operator from electric hazards. Unit is weathertight and dust proof and weighs only 70 lb. Ratings are 15 hp at 440 v and 7½ hp at 220 v, 3-phase.



Price competes with NEMA size 1 starters. Standard features are fusible main disconnect, selector switch, 15 minute timer with skip-a-day, dual primary control transformer and magnetic starter with adjustable 3-phase bi-metallic overload relay. *American Kloeckner-Moeller Corporation.*

Circle number (13) on reply card.

Automatic Drilling Controls. Any desired weight on the bit can be pre-selected and automatically maintained by means of the Automatic Drilling Control. The "Oilwell" No. 10 Unit (illustrated) is recommended for drilling depths to 10,000 ft. A larger No. 15 Control is available for heavier duty requirements. Unit includes

a multi-cylinder positive-displacement pump powered by the weight of the drill string, which is transmitted by the drilling line through the drawworks drum shaft. *Oil Well Supply Division of United States Steel Corporation.*

Circle number (14) on reply card.

Electro-Hydraulic Operators. Line of completely self-contained electro-hydraulic valve operators has been developed by Fisher Governor Company. They produce high performance without the use of electronic amplification, utilizing only simple direct current actuated force motors to operate the hydraulic pilot. Nozzle-flapper combinations are used in the pilot to control hydraulic pressure, eliminating sliding plate or spool type valves which are easily stuck.

Type 340 can be mounted on valve sizes ½ to 4-in. and will develop stem thrusts up to 600 lb. Type 350 can be mounted on valve sizes ½ to 16 in. and develops stem thrusts up to 2000 lb. *Fisher Governor Company.*

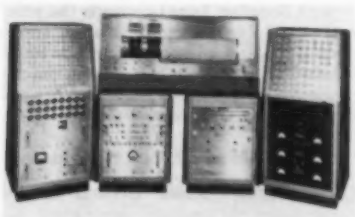
Circle number (15) on reply card.

Improved Mud Test Kit. Newly designed and improved No. 821 mud testing kit replaces Baroid's No. 820 unit. Kit comes 26½ by 25 by 11 in. stainless steel cabinet weighing only 75 lb. It is equipped with wall mounted filter press which can be

operated manually or from the rig air supply. Kit is completely equipped to perform all necessary rig mud testing for optimum drilling operation. *Baroid Division, National Lead Company.*

Circle number (16) on reply card.

Geological Analyzers. The MS-12 GeoData System processes FM and Direct recordings. It provides a record cross-section which is pen-recorded on paper and can be photographically reproduced. Cross-sections can be isopached or set to a desired reference plane. The graphically presented information is also permanently stored on magnetic records.



Magnetic or visual records which have been trace-mixed, filtered, corrected for weathering, elevation, and normal moveout can be made with GeoData equipment. Filter analysis may be made of field records by playing the same record back through several filters and displaying it as a pen-written paper recording. *Southwestern Industrial Electronics Company.*

Circle number (17) on reply card.

Portable Well Logger. Radioactivity logging of shot holes and wells in the petroleum industry is facilitated by a new shallow depth geiger counter unit. It is designed for logging up to depths of 1000 ft. The down-hole tool is 1 in. in diameter and 15½ in. long. Meter package provides sensitive readings of radiation level and the unit is also equipped with phone jacks to permit audio monitoring or connection of recorder. *Tracerlab Inc.*

Circle number (18) on reply card.

Gage Safety Case. New gage case construction, "Safecase," provides maximum safety on dangerous installations. A solid front protects the gage face and a thin stainless plate, covering the entire back of the case relieves all explosive pressures. The back plate is held firmly to the case by 2 holding screws-eliminating all possibility of the back plate becoming detached in the event of a blow-out. *Jas. P. Marsh Corporation.*

Circle number (19) on reply card.

Automation Motor-Valve. Developed by The Guiberson Corporation is the Type T1500 motor valve suitable for production testing equipment and automation applications. Unit is a threaded, 3-way, full-opening, high pressure valve designed for 3000 psi test pressure, 1500 psi working pressure. Diaphragm operating pressure

is 25 psi. Valves may be 2 in. full open Neoprene, ¾-in. Colmonoy trim, or a combination of these two. Field connections are 2-in. line pipe. *The Guiberson Corporation.*

Circle number (20) on reply card.

Cam-Less Integrator. Type 14A pneumatic integrator is unique in that it requires no cams for square root extraction, and provides continuous integration of flows to within 0.5 percent accuracy. A jet of air produced by a 3-15 psi measurement signal spins a turbine wheel which is geared to a counter which totalizes the flow.

Flow change is instantly reflected in a change of wheel speed. Centrifugal principle is used to extract the square root factor so that integration of flow is linear. *The Foxboro Company.*

Circle number (21) on reply card.

Stationary Tester. This is a quality gage tester suitable for testing to 25,000 psi pressures. Pressure increments of 1 psi can be read directly over the entire 25,000 psi range. Featured in the Style CD-3 is a positive drive connected directly with the balance spindle, so improved as to eliminate slippage. *Crosby Valve & Gage Company.*

Circle number (22) on reply card.

Differential Pressure Controller. Model 237 Controller features the Barton Model 199 rupture-proof bellows unit. The controller is furnished in differential pressure ranges from 0-20 in. to 0-50 psi with static pressure ratings up to 6000 psi. A variety of housing materials are available including aluminum, steel, alloy steel and stainless steel. Standard control actions include on-off, differential gap and proportional. Proportional plus reset or proportional plus rate are optional. *Barton Instrument Corporation.*

Circle number (23) on reply card.

Constant Flow Controller. Kobe's constant flow control valve provides a constant flow rate for any given setting of the handwheel regardless of fluctuations in downstream pressure. This angle-type valve is equipped with 1-in. fittings, handles pressures to 5000 psi, and volumes from 0 to 1500 bbl per day. A dust-cap attached to the handwheel reveals turn calibrations which permit micrometer adjustment of the valve's opening. The valve was designed by Kobe and Grove Regulator Co. engineers and is being manufactured by Grove exclusively for them. *Kobe, Incorporated.*

Circle number (24) on reply card.

Scintillation Counter. Mount Sopris Instrument Corporation announces a new airborne-carborne scintillation counter, Model SC-156A, for use in geophysical exploration. Improvements offered include: (1) Higher count rates for a given radiation field, (2) extended detector response at the low or soft end of the radiation spectrum, (3) calibrated zero displacement to permit the use of increased sensitivity for a given background, and (4) increased stability. *Mount Sopris Instrument Corporation.*

Circle number (25) on reply card.

2 Pen Recording Potentiometer. New recording potentiometer features 2 pens both writing margin to margin on a single 5-in. strip chart producing 2 continuous records in a small space. The recorder is available with 1 front set limit switch and 3 back set limit switches on each pen.

The instrument features such specifications as 0.5 percent accuracy on each pen, sensitivity 0.14 percent of scale span, maximum source impedance of 1000 ohm per mv of span. MV or TC calibration case extends only 13 in. behind the panel face. *Westronics, Inc.*

Circle number (26) on reply card.

Bag Cutter Saves Time and Labor. A bag cutter for bagged refractories, cements, chemicals, etc., that cleanly cuts paper sacks in half for ease of lifting and emptying has been announced by Ridley and Company. To conserve labor, bags can be opened in advance of use with this device and stacked at the job site for rapid, convenient use. *Ridley and Company.*

Circle number (27) on reply card.

Package Control System. A. W. Cash Company, in conjunction with Sparton Corporation, has developed the first package control system for remote positioning of cone, butterfly, plug and ball valve; sliding stem valves; such variable speed mechanisms as throttles and rheostats; and other final control elements. Known as the Cash standard-Sparton series 300 packaged control system, it can control pressure, flow, surge, liquid level, proportioning, speed, and other process variables at distances of a few feet to many miles with one operator at one central location. *A. W. Cash Company.*

Circle number (28) on reply card.

NEW Literature

For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

Actuator for Low Level Signals. Bulletin 38.3 describes new electro hydraulic valve actuator. This new actuator is designed for use with low level a-c or d-c signals from electronic controllers and measuring elements or remote positioning devices. It can be mounted on valves having ½ to 1½-in. stroke, requring less than 200 lb thrust. *Askania Regulator Co.*

Circle number (29) on reply card.

Instrumentation Catalog. Peschel Electronics 1957 catalog features high voltage test equipment. Applications and specifications are given for each product together with illustrations. *Peschel Electronics, Inc.*

Circle number (30) on reply card.

Rotometer Transmitters. Bulletin 170 has been published by the Brooks Rotameter Co. to present full data on their line of pneumatic and electric transmitters. These transmitters are designed for use with the Brooks rotameter and are said to utilize advanced design features in a new approach to standardization and in line performance. Bulletin describes with schematic drawings the details of operation as well as the design characteristics of these devices. *Brooks Rotameter Company.*

Circle number (31) on reply card.

Rig Instrument Catalog. A new catalog is now available on Line Scale weight indicators and mud pressure gages. Well illustrated, the booklet provides complete specification and prices on the various models produced by the company. *Line Scale Company, Incorporated.*

Circle number (32) on reply card.

Advanced Telemetering. A brochure has been made available by Norwood Controls regarding their ElectroSyn Signal Generator System. This system is composed of a signal transmitter magnetic servo amplifier and null-balance indicating receiver. In measuring pressure or flow, the signal transmitter (by means of a twisted Bourdon Tube) converts the process variable into a shaft rotation which in turn operates a rotary differential transformer. Output is an a-c voltage exactly proportional to the variable. *Norwood Controls, Unit of Detroit Controls Corporation.*

Circle number (33) on reply card.

Channel Guard Radio. General Electric communication products department has published its first bulletin on its new "Channel Guard" tone squelch device, designed to reduce interference problems in 2-way radio systems. The bulletin — ECR 449 — describes how unwanted signals and transmissions may be avoided if the new device is installed in new radio systems or those already in use in the field. *General Electric Company.*

Circle number (34) on reply card.

New Tank Gage. A 4-page bulletin gives full, complete details of the construction and operation of the Oceco Division's new No. 30 Tank Gage; said to be highly accurate, completely automatic, easy to read, readily adapted to remote reading, easily installed on either new tanks or tanks already in service. *Oceco Division, The Johnston & Jennings Co.*

Circle number (35) on reply card.

Switches for Temperature Measuring Circuits. Thermo Electric Co., Inc., has completed a new bulletin, No. 24-1, on its key or push-button selector switches for thermocouple or resistance bulb circuits. These switches provide a fast, convenient means of frequently checking many thermocouples or resistance bulbs, switching them from one instrument to another, or switching one instrument to many different measuring points. The bulletin describes in detail the various types of 2-and 3-position key switches and push-button switches. *Thermo Electric Company, Inc.*

Circle number (36) on reply card.

Magnetic Tape Data. The effects of heat, humidity, and tension on magnetic tape are discussed in "Sound Talk" Bulletin No. 35 which is available from Minnesota Mining and Manufacturing Company. The 3-page bulletin, titled "Physical Limitations of Magnetic Tape," is illustrated with 3 graphs which show stress characteristics of the different tapes of "Scotch" brand magnetic tape. *Minnesota Mining and Manufacturing Company.*

Circle number (37) on reply card.

Phasemaster. New bulletin on the recently developed Model PM-1B Phasemaster is now available from Statham Development Corporation. This bulletin describes in detail the specifications and applications of the Phasemeter as well as significant features. In addition, the bulletin contains illustrations and a diagram of the new unit. *Statham Development Corporation.*

Circle number (38) on reply card.

Acoustic Well Logger. Just released is data on the new improved sonolog used for measuring the fluid level in producing oil wells by the acoustic method. Brochure includes application data, specifications, prices and other information pertinent to the selection of application of this device in fluid level measurement. *Keystone Development Company.*

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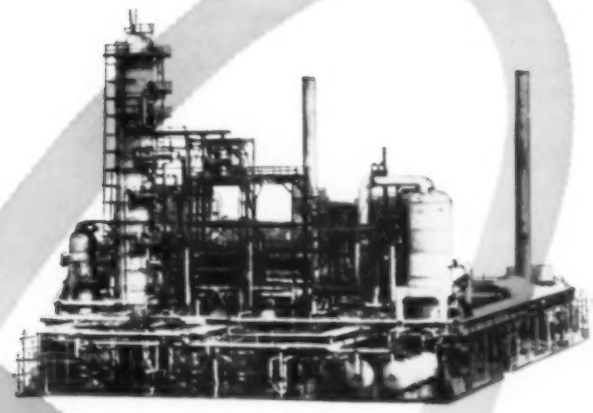
Protect Your Engine. Lubrication is the most important single factor in engine operations, and viscosity is the main property of oil which measures its ability to lubricate. Recognizing this, the viscometer has been designed to fit right on the engine and indicate to the operator continuously the viscosity of the oil in the crank case. The device is a continuous operating viscometer which operates off of the lubricant pump on the engine. Indicating instrument may be mounted on the engine or on the engine control board. *Visco-Meter Corporation.*

Circle number (40) on reply card.



Sun Ship has furnished equipment for many major oil companies in America

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DUPLEX PRIME SURFACE TUBE

U-BEND PALLETS

Duplex TYPE S/T

This tube also is designed for specific corrosive conditions. But, like Trufin, it has integral fins—will boost heat transfer efficiency. It can be used instead of prime surface tube.

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A high-finned, lightweight aluminum tube is mechanically bonded to an interior liner of the alloy which best beats your corrosion hazard. It provides maximum heat transfer and trouble-free performance at low cost.

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New Projects in refining gas processing petrochemicals

A 1630 BPD Alkylation Unit is to be built by Standard of Indiana at its Mandan, North Dakota, refinery. Construction, etc., will be done by Foster Wheeler Corporation. The unit is licensed by Phillips Petroleum Company and uses a hydrofluoric acid catalyst. Completion is planned for September 1958.

The First Commercial Hexane Isomerization Unit is under construction at Atlas Processing Company's plant in Shreveport, using the Penex process to handle 3500 BPD. The unit will make several streams, including one of 98 Research octane number, and one of 90 RON, will be onstream early in 1958.

A 22,000 BPD Refinery at Emden, Germany, will be built by Erdoelwerke Frisia. Financing will be partly by American Independent Oil Company, also by Erdoel and two other companies.

Expanding two crude units from 30,000 BPD to 45,000 BPD each is the major step in adding 30,000 BPD capacity to its Richmond, California, plant, Standard Oil Company of California has announced.

A Catalytic Reformer, an Alkylation Unit and auxiliaries will be built by American Petrofina Company of Texas at its Mt. Pleasant, Texas, refinery (formerly American Liberty Oil Company). Project cost is about $3 million; construction time will be 12 to 14 months. Specifications are now being drawn, available to bidders by September 1, with bids to be opened by November 15.

A New Asphalt Plant will be built by Cities Service Company (Pennsylvania) to replace its 7500 BPD plant at Linden, New Jersey. "A substantial increase" is planned, with completion set for late summer, 1958.

Esso Standard Oil Company President Stanley Hope told Esso employees that the company's capital outlays for new refining and marketing facilities total $117 million — nearly double the firm's after-taxes profit of about $60 million. Return on investment in 1956 was about seven percent, according to Mr. Hope.

A 400 Ton Per Day Sulfuric Acid Plant to operate on refinery acid sludge will be built by Stauffer Chemical Company at Hammond, Indiana, adjoining the great East-Chicago-Whiting refining center. To be onstream by July 1958, the plant will be highly automated and will cost upwards of $4 million. Stauffer now has seven acid recovery plants in various parts of the country.

A Hydrocarbons Recovery Plant will be built for Columbia Gas System at Kenova, West Virginia. The fractionation unit for the raw products will be located at Siloam, Kentucky, with a pipeline to connect the two plants. J. F. Pritchard & Company will build the two plants; the first to cost about $8 million and the fractionation plant to cost about $5 million. The extraction unit will process about 170 MMcf of raw gas daily. Development of a petrochemicals complex is being considered.

Leonard Refineries of Alma, Michigan, has announced a multi-million dollar expansion program. Included are a 7500 BPD fluid catalytic cracking unit and a 43-mile pipeline to a new terminal at Lansing, Michigan. Ralph M. Parsons Company will build the cracker, with completion scheduled for August 1958.

Gulf Oil Corporation will build a 12,000 BPD Pentane Penex Hydroisomerization unit at its Port Arthur, Texas, refinery. The process, licensed by Universal Oil Products Company was jointly developed by Gulf and UOP.

The 55,000 BPD Refinery for Panama Refining & Petrochemical Company will be built in Portobelo, Panama, in Colon province on the Caribbean Coast. The first plant in the country, it will be built by Foster Wheeler Corporation—for $33 million. Panamanian President de la Guardia has given 360 acres on the harbor to the company, and has declared the Portobelo harbor an international port.

Sulfuric Acid Plant Capacity at the Consolidated Chemical Industries, Baytown, Texas, plant will be doubled later this year. CCI is a division of Stauffer.

A Urea Plant, rated at 100 tons per day will be built by Spencer Chemical Company at Henderson, Kentucky. Initial operations are scheduled for mid-1958.

A 4400 BPD Unifiner, a 5100 BPD Platformer, and a 7100 BPD Distillates Unifiner will be built by The Refining Engineering Company for Farmer's Union Central Exchange at its Laurel, Montana, refinery.

Thirty Million Gallons of Benzene Annually will be produced in a new unit to be built by Gulf Oil Corporation at its Port Arthur, Texas, refinery, one of the largest refineries in the world. Unit, to be built by Procon, Inc., will be onstream late in 1958, and will include a catalytic reformer and a purification section.

A 35,000 BPD Crude Unit will be constructed for Utah Oil Refining Company at Salt Lake City by Fluor Corporation, Ltd., at a cost of about $2 million, and will be completed by mid-1958. Fluor just completed a 5500 BPD Ultraformer for Utah at the same refinery.

Forty Million Pounds Per Year expansion of Monsanto's styrene monomer unit at Texas City, is planned. Completion is scheduled for mid-1958.

Acrylonitrile, an Intermediate for Plastics, rubber and other products will be made by Dow Chemical in a new unit to be built at Freeport, Texas, in 1958, which will start production early in 1959. The product will be made from acetylene and is one of the first of Dow's products to start from that important chemical.

A 200-Ton Per Day Sulfuric Acid plant will be built for Platte Chemical Company at Casper, Wyoming, by Leonard Construction Company, to supply that region with acid for several purposes — uranium recovery, petroleum processing, etc. Unit will cost $2 million and will go onstream by July 1958. It will use recovered sulfur from natural gas, refinery gases, etc.

A 3700 BPD Platformer, including a prefractionator, will be built for Phillips Petroleum Company at Woods Cross, Utah, by Procon, Inc. Construction will start this fall and is to be completed by the spring of 1958.

A 35 Million Cu Ft Per Day Gas Processing Plant will be built by Kansas-Nebraska Gas Company, Inc., in Big Spring field of southwestern Nebraska, to yield 25,000 gal propane daily, also 6000 gal natural gasoline and 8000 gal daily of butane.

Ethyl Research Performance of Today's

by T. W. Warren

Director, Refinery Technology, Ethyl Corporation Research Laboratories

A premium fuel being road tested in one of Ethyl's controlled-weather rooms that duplicates road conditions exactly.

Reports on Premium Fuels

NINETY-ONE premium gasolines and 12 third-grade super-premium fuels have been tested on the road and in the laboratory in a research program recently completed by Ethyl's Detroit Research Laboratories.

The results of this investigation have been published in a 140-page report entitled "Antiknock Behavior of Premium Motor Fuels, 1957", now available to all companies in the Oil and Automotive Industries.

The fuels tested were submitted by 83 refineries of 48 American companies. These refineries produce 75 per cent of the motor fuel in the United States. Seven Canadian companies, producing an appreciable percentage of Canada's gasoline needs, also submitted fuel samples for testing.

Each Gasoline Tested 32 Times

Five 1957 cars normally requiring premium fuels, and three cars equipped with experimental 11 to 1 compression-ratio engines were used in the tests. A minimum of two Modified Uniontown and two Modified Borderline ratings were obtained for each gasoline in each car, a total of at least 32 road ratings for each fuel sample.

Extensive laboratory data, including determinations of tetraethyllead susceptibility, hydrocarbon type, and bromine number, were also obtained and are included in the report.

Test Results Point to Future Gasoline Developments

The broad sampling of premium fuels tested gave an accurate picture of today's premium gasolines and how they perform in the cars of today and in the higher compression engines of tomorrow. A complete analysis of all the test data led to the following conclusions affecting refining economics:

1. Sensitivity (the difference between Research and Motor octane number) often is an unreliable measure of road performance through the normal speed range.

2. Research and Motor octane numbers can be used to predict road performance at low speeds but are less reliable at intermediate and high speeds.

3. At higher speeds, road performance increases when the aromatic content of the gasoline is increased.

The 103 premium and super-premium gasolines in these drums were tested for Ethyl Corporation's 1957 premium fuel survey. This is the fifth premium survey conducted by Ethyl since 1946.

An important by-product of this program was the development of a system for calculating the road octane number of a gasoline. This development will permit individual refiners to determine the "road octane number" of their gasoline blends using the results of simple laboratory tests.

How Ethyl Research is helping you

Since World War II, Ethyl Corporation has investigated the laboratory and road performance of premium-grade gasolines in 1946, 1949, 1951 and 1954. During this period, the number of fuels analyzed has increased from 12 gasolines in 1946, to 63 in 1954 and 103 in 1957.

"Antiknock Behavior of Premium Motor Fuels, 1957" is one more example of Ethyl's continuing service to the Oil Industry. Copies can be obtained from your Ethyl Representative or by writing Ethyl Corporation, 100 Park Avenue, New York 17, N. Y.

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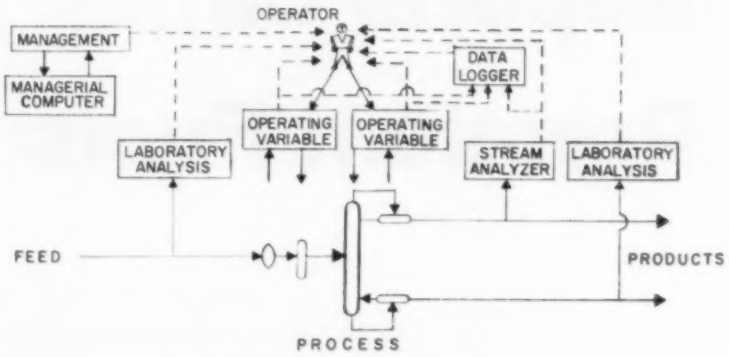
Automation is Growing Up



Today's supervisory-type control system.

What Is Automation?

ARE today's refinery processing units automated? In a sense, yes. But in the broader context of the word, no. Before making a decision on this with respect to your own operations, it is necessary to know what automation is.

There is disagreement on who coined the word "automation." Some claim that it was Del Harder, now vice president in charge of manufacturing for Ford Motor Company, back in 1947.[1] Another source credits John Diebold, now a recognized expert in the field, who created the word while a young graduate student.[2] Be that as it may, their motives were the same: To create a shorter, easier-to-pronounce word than "automatization."

Definitions of the word are, literally, a dime-a-dozen. While they may vary, though, there are very few with which we cannot agree. Harder calls it "a concept which embraces our planning of all manufacturing processes." In a book published in 1952, Diebold defined it as "denoting both automatic operation and the process of making things automatic." A still more specific evaluation of the word has been made by Milton H. Aronson, editor of Instruments and Automation: "Automation is a substitution of mechanical, hydraulic, electronic, and electric devices for human organs of decision and effort."[1]

All of these definitions are acceptable to most people. Thus, it can be seen that automation is *not* a term denoting a precise condition of existence or operation. When stating that you have an automated plant, you must qualify the word with an adverb, to connotate the *degree* of automation. Here's why, in more technical terms:

Automation means the replacement, to some degree, of the process operator or engineer in the control loop. In today's process control systems, the operator brings back information about the condition under control for comparison with the target value, and makes adjustment in the controller output accordingly. This is "feedback," but we have an "open" control system because it is a man that interprets the data and makes adjustments. In a "closed" or more fully automated system, the operator's brains and hands are replaced by a mathematical "model" — either analog or digital — that replaces his processes of thought and action.

Where Are We Today?

The next section, "How Today's Control Techniques Developed," shows that we do have partial automation in our present technology. And, certain parts of the system are fully automated. But, supervisory control of the *entire* process is in the hands of the operator.

There are no process units on record that have 100 percent feedback. There are units that include data loggers and even electronic computers that calculate process variables. Yes, this is more complete automation that heretofore realized. But, the control loop is still "open." The operator must absorb these recorded and derived data and feed back to the process controllers his interpretation of how the entire operation should be conducted, consistent with managements' aims for maximum yields, profits, and/or quality, etc.

This is the process of "optimumization." Perhaps we can introduce a better term — OPTIMATION — to describe the process of optimizing a process operation or function.

As the ensuing pages will make clear, we have come a long way with instrumentation and control systems. Large, unwieldy housings have been cut down to an economical size thanks to miniature units. Response has been improved by force-balance cells on pneumatic transmitting and control circuits. And, the world of electronics makes possible remote — or local — control almost instantaneous, depending on the dynamic response of the system.

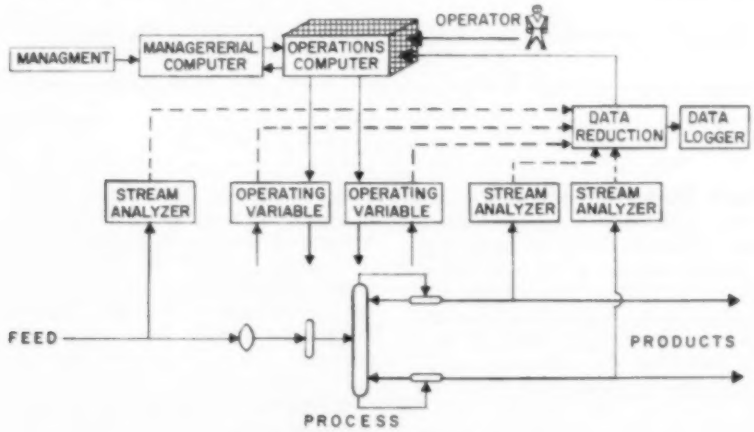
"And when did you first notice this electronic control panel was smarter than you . . .?

[1]Grabbe, E. M., "Automation in Business and Industry," John Wiley and Sons, Inc., New York, 1957.
[2]M. L. Powers, Petroleum Refiner, Vol. 35, No. 1.

Automation 57

...a feature report by the editors and outstanding authorities in the field of instrumentation and control

Whit Downer
Editor, The Refining Engineer



Tomorrow's automatic control system.

Electronic computers of all sizes, shapes, and forms are available. Thus it can be said that we have most of the basic tools required for full automation. Note that I said that we have *most* of the tools. What is missing?

Missing Links in the Chain

Overlooking for the moment the aspects of cost, there are two key links that have to be built before the chain of technology leading to full automation can be completed. First is the availability of continuous analyzers that will instantaneously measure a key component or characteristic in the feed and product streams. Second is knowledge of the kinetics and dynamic response of the process system —including all of its components.

Technology will provide these links in time. The links have already been provided in a few instances. We are speaking in the broad sense of the term.

Continuous analyzers have been developed for literally thousands of applications. But, for example, full automation of a catalytic cracking unit would be dependent upon continuous analysis of carbon on regenerated catalyst, so that combustion air rate could be adjusted accordingly, or so that reactor holdup could be changed to permit constant conversion.

Similarly, our mechanical brain would have to know the dynamic response of the regeneration system in order to properly compute the amount of change that must be made in combustion air flow rate, also taking into account effects on the reaction side. Albeit our knowledge on these matters is vast, but not adequate to program a computer that would replace the present-day operator's judgment in handling such a problem.

So, we have seen just one example of where man's intelligence and judgment must suffice until a machine comes along that will do the complete job.

Where Do We Go from Here?

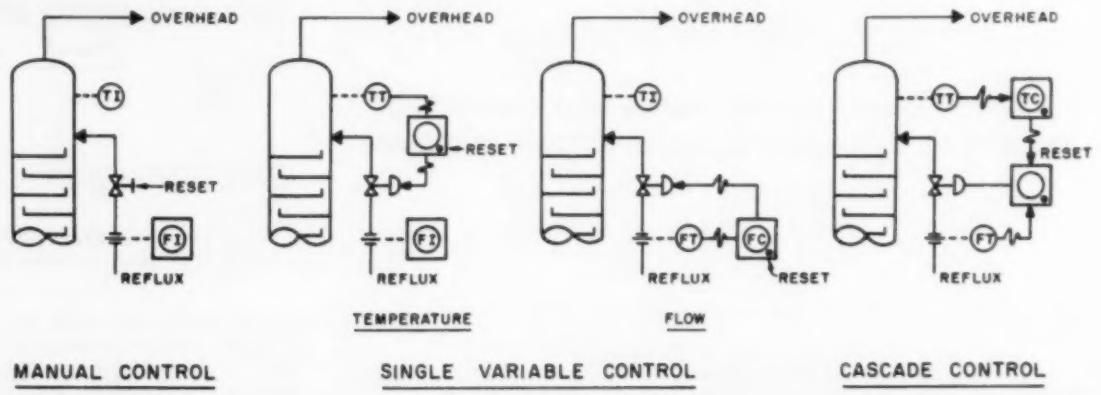
Writers and orators have expended millions of words on the impact of automation in today's society. Consequently, we'll let them deal with its sociological implications. Our major criticism of their oft long-winded arguments is the implication that automation is like a thunderhead in the distance. We can see it coming, and when it does, the rain starts falling with a big roar of thunder — "bang!" We are now in an age of automation. To be sure, we are in a transition stage, but just at another level in the gradual process of technological and social evolution — NOT revolution.

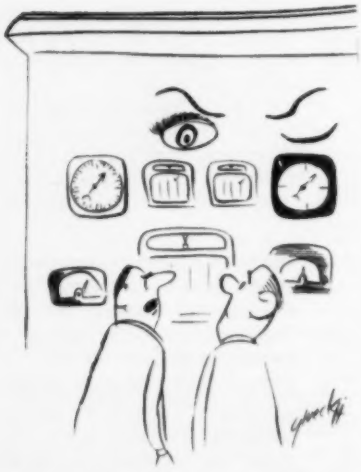
As has always been the case, the steps that will be taken in the future in regard to moving from partial to complete automation in most phases of refining and petrochemicals depend upon:

1. The tools—further development of the primary elements, controllers, and control elements that will replace the operator's five senses and his muscles.
2. Justification — whether further automation will pay for itself is influenced by labor costs, adequacy of present-day systems, product and raw material price and quality, and — possibly — the desire to make progress for progress' sake.
3. Availability of capital — the last few steps in moving from partial to complete automation is costly, albeit justified. Competing projects, such as another new process unit or modernization of an existing unit also call for money — money that is quite subject to the law of supply and demand.

To say *when* all of these factors will favorably combine "across-the-board" would be sheer guesswork. We see it now, in some isolated instances. Suffice it to say, therefore, that we are in a time of extensive development in the field of automation — we are growing with it, and it with us.

How Today's Control Techniques





"We added the electric eye to discourage the poker playing on the night shift..."

Manual Control

It is necessary to crawl before walking, and today's control systems have been developed in the same manner. Using a fractionator reflux control as an example, we can trace the development of a modern control system, and the reasons for it.

Manual control of the reflux stream was, to say the least, hectic. The operator attempted to maintain a constant tower top temperature, despite possible pressure surges or temperature surges in the reflux stream. Manual response to the dynamic system was, in all probability, slow. Consequently, considerable surging or variation resulted.

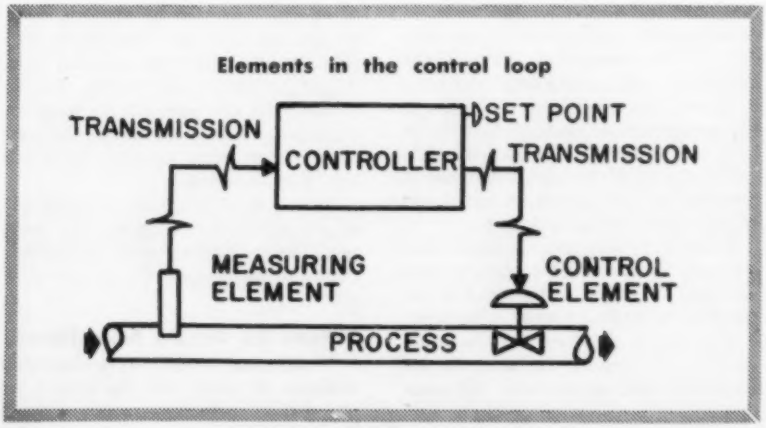
Single Variable Control

The single-variable control system is the building block for all other types of control systems. It has three basic parts — the measuring element, the controller, and the control element. The measuring element senses the process condition, the controller determines what is to be done about it, and the control element does it.

Elements in the control loop. There are, of course, auxiliaries and further components in the total system. Transducers may convert the signal from the measuring element into a signal that the control element may more readily read. The controller may include several elements that will set the rate of response of the control system to changes as measured in the process. And, the controller will have a set or control point that may either be fixed or adjustable. A transducer in the controller may convert the control signal to a power signal to the control element. Or, there may be a transducer in the control element that will convert the control signal — from electric to pneumatic, or from square root to linear, etc.

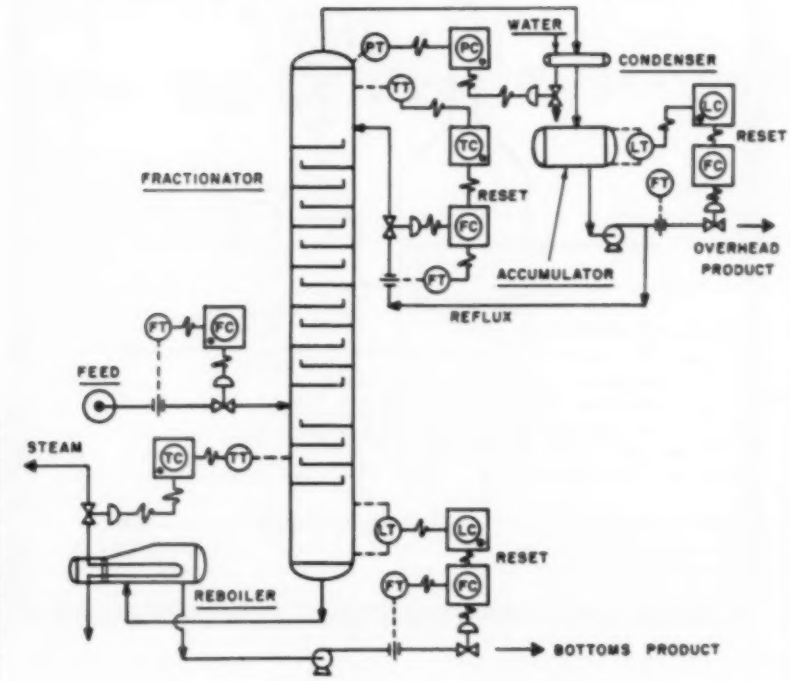
Within the control element we have two basic parts, the power element or driver, and the control surface. For example, we have the pneumatic or hydraulic motor as the driver in a control valve, and the body or control surface that actually cause change in the pressure drop — or rate of flow — through the valve.

Integrating the entire system is signal transmission, either a gas-filled, liquid-filled, or electrical circuit.



Developed

fractionator reflux control is a good example



CASCADE CONTROL OF A FRACTIONATING COLUMN

Symbols

FI — Flow Indicator
FT — Flow Transmitter
FC — Flow Controller
TI — Temperature Indicator
TT — Temperature Transmitter
TC — Temperature Controller
PT — Pressure Transmitter
PC — Pressure Controller
LT — Level Transmitter
LC — Level Controller

Note:
Symbols denoting flow, temperature, pressure, and level indication and for recording are omitted for simplicity.

There are two examples of single-variable control shown in the fractionator reflux circuit. Temperatures in the top of a fractionator are, of course, regulated by the reflux rate of flow. In the first example, tower top temperature controls the reflux rate of flow. There is a serious drawback in this single-variable system, however. Any changes in the reflux rate caused by pressure surges downstream of the control valve would cause a change in tower top temperature. Temperature processes are slow, thus corrective action would also be slow.

The single-variable flow control system would be more ideal if there were considerable pressure surging in the system. The flow controller would be quick to sense a change, and the control action initiated more promptly. But, the object of our system is to control tower top temperature, and the flow control circuit does not satisfy this requirement . . . the operator would have to control this manually by adjusting the set point on the flow controller.

Cascade Control

Better features of the temperature control system and the flow control system can be combined into what is known as a cascade control system. Such a system is, by definition, one in which the reference signal or set point is the control or output signal from another controller.[1]

Thus, in our fractionator reflux control circuit, the output from the temperature controller establishes the set point for the flow controller. At the same time, the flow controller would rapidly detect pressure changes, i.e. flow changes, in the system, and make immediate adjustment.

The control system shown for an entire fractionating column is illustrative of how cascade control can be used in several instances. Tower top temperature is controlled by a cascade system, with the temperature controller resetting the reflux flow controller. A level controller on the overhead accumulator resets a flow controller on the overhead product line. Bottoms product is similarly controlled.

Single variable elements in the control system include the steam flow rate to the reboiler, directly actuated by temperature above the second plate in the tower. Feed to the tower is on flow control . . . this is optional, however, since the rest of the tower is instrumented to absorb changes in feed rate without marked swings in operating conditions. And, tower pressure is regulated by flow of water through the overhead condenser, on pressure control from the top of the tower.

Note the possibilities for other cascade control loops in the system. Whether or not needed, would of course, depend on the operating characteristics. For example, if steam pressure is subject to considerable variance, it would be advisable to incorporate a pressure controller into the system upstream of the control valve. The pressure controller would be reset by the temperature controller operating on temperature above the second plate. Thus we would have a more effective temperature control system, one less subject to cycling due to pressure surges in the steam header.

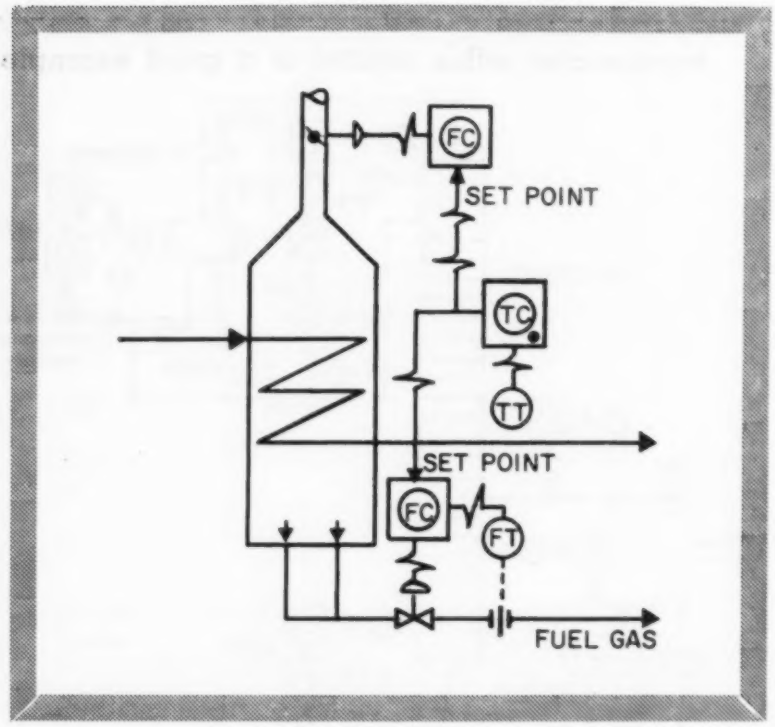
cascade control of a process heater

Coordinated Control

A hypothetical induced-draft furnace combustion control system is an example of a co-ordinated control system. In a process tubular heater, the primary objective is to control coil outlet temperature, in turn regulated by energy input (firing rate) to the furnace. Assuming that fuel gas heating value (composition) is constant, the combustion air rate and fuel gas rate should be in direct ratio. Therefore, the coil outlet temperature can be used to reset both the fuel gas rate of flow and the stack damper.

A forced-draft furnace would incorporate coordinated control this way: The coil outlet temperature controller would reset the fuel gas flow control and the air inlet damper. The stack damper would be on firebox pressure control.

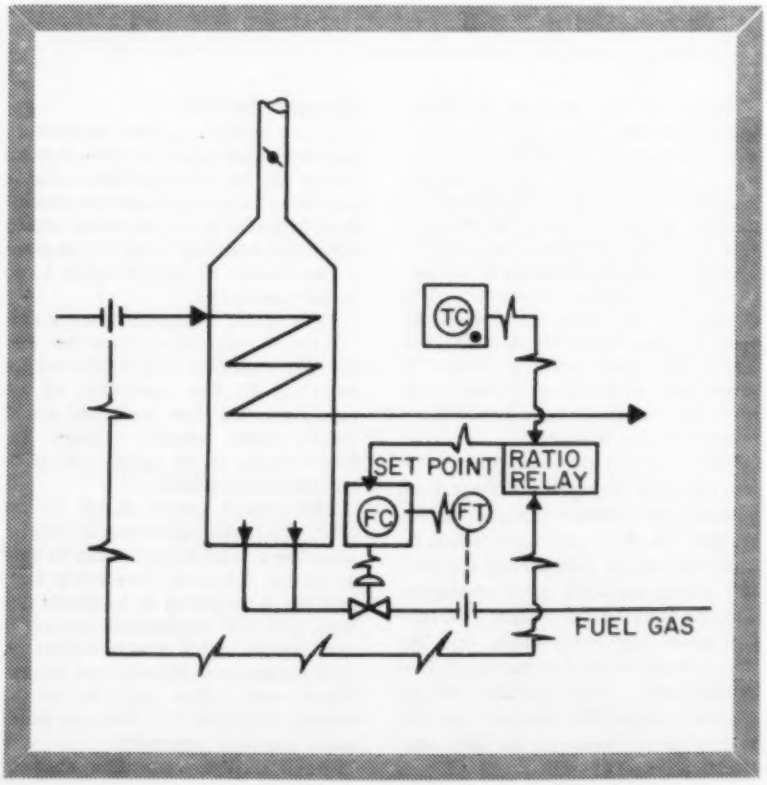
Thus we arrive at the definition of a coordinated control system; one in which the output from a single master controller regulates two or more secondary controllers.



Ratio Control

If the ratio between fuel gas rate of flow and combustion air rate is not fixed . . . perhaps due to fluctuation in fuel gas composition . . . it becomes necessary to modify our cascaded, coordinated control system. This can be done by adding a ratio relay unit. This ratio relay unit could be reset by stack temperature or some other dependent variable.

It might also be desirable to modify the response rate of the system — relatively low because we are on temperature control — by the more sensitive rate of flow technique. A flow transmitter on the oil inlet would feed one side of a ratio relay, the coil outlet temperature, the other. This ratio relay would, in turn, reset the fuel gas flow controller. Thus we have three inter-related, but different variables — oil rate, fuel rate, and coil outlet temperature — influencing the final control element, which is the fuel gas control valve.



[1]Grabbe, E. M., "Automation in Business and Industry," John Wiley and Sons, New York, 1957.

There are a variety of control systems available. Selection must be based on process behavior and measurement lag

How Do Control Systems Behave?

Response of the control system to a change in the process or an input signal from the operator is the most important factor in the selection of a control system. Items such as lag, deviation, and cycling enter into the picture.

All are present in each of the elements of the control system to some degree. In most cases, the action of the controller must be designed to compensate for these factors — in the process itself, in the measuring element, and in the final control element.

In the example shown for ratio-cascade control of a process furnace, the ratio controller takes into account the relatively slow response of a temperature change by modifying the input to the fuel gas flow controller according to flow through the coil.

Response of Measuring Elements

Measuring or primary elements are used to indicate chemical composition, pressure, level temperature, and flow. And, many types of flow meters are, in reality, based on interpretation of a differential pressure. In this category we can include the orifice meter, pitot tube, and venturi.

Chemical composition measurement is an on-off operation in many instances. Into this grouping can be included the mass spectrometer, vapor phased chromatograph, and emission spectrometers. These instruments are not placed in the control loop, for obvious reasons.

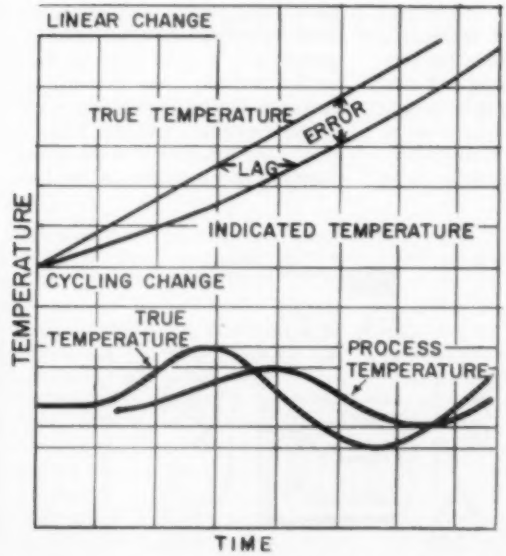
Other units, such as continuous flue gas analyzers or oxygen analyzers have lags ranging from five minutes to a half an hour, but are continuous. They are very often found in a control room, but again are not in the control loop.

On the other hand, refractometers, infra-red analyzers, etc., exhibit little or no lag, and can be included in the control loop in certain instances.

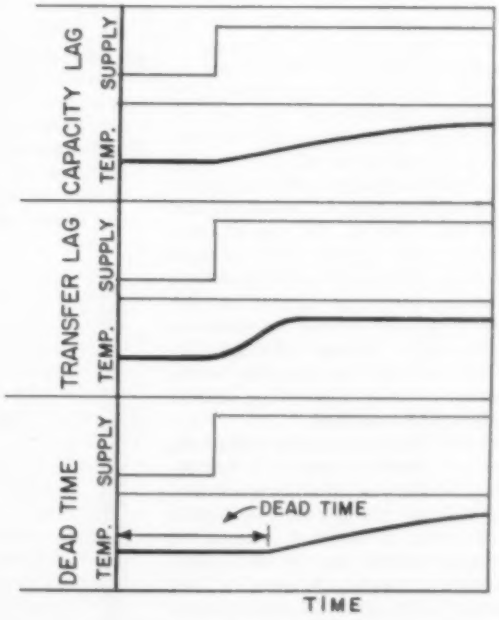
Pressure and flow measuring elements used in process control are relatively fast to respond to a change in the process which we are measuring. For all intents and purposes, response of pressure-measuring devices — the U-tube manometer, the diaphragm, and bourdon tube — is rapid enough not to present serious problems. The same is true of the popular types of flow meters. Most important of these, from the process control point of view, is the orifice meter, followed by the area meter (rotameter), the positive displacement meter, and finally the pitot tube.

Liquid level, as measured by float-type, differential-pressure, or electronic devices can also be included in the realm of rapid response, at least to the extent that compensation for response can be overlooked *in general* so far as the control element is concerned. Note that the term *in general* was used. There are exceptions to every generality, and each control problem must be so considered.

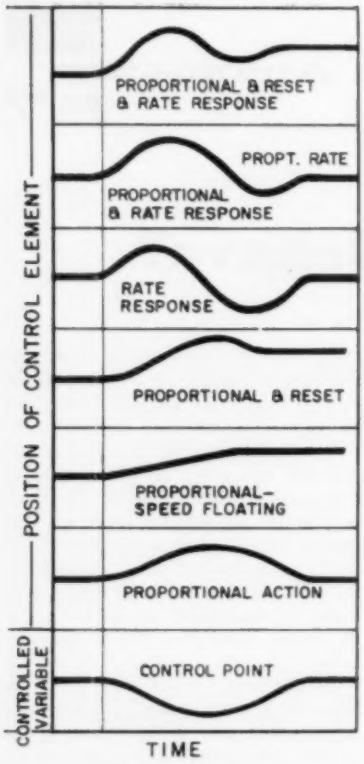
Temperature is measured either by



Indicated temperature vs true process temperature in a changing system.



Types of process lag.



Types of control action compared.

pressure or thermo-electric elements. The more popular thermo-electric elements include the thermocouple, resistance thermometer, and radiation pyrometer. Pressure elements include gas-filled, liquid-filled and vapor-pressure units. All three have slower rates of response than the thermo-electric units, but have their specific applications — especially when accuracy is paramount. And, to complete the list of temperature measuring elements, the bi-metallic thermometer can not be overlooked. It, of course, has the lowest rate of response of all.

Two time constants influence the response of temperature, measured and controlled. First is the rate of heat transfer to the process. Rate of heat transfer is influenced by the resistance at the heat exchange surface and the thermal capacity of the hot medium and the cooler medium. Also influencing the rate of heat transfer is the velocity, viscosity, and fouling characteristics of the mediums.

Second, the temperature measuring element is usually placed in a thermowell, as in the case of a thermocouple. The bulb of the gas or liquid-filled thermometer is another example of this second-order lag. In both cases, the time-consuming process of heat transfer enters into the measurement picture.

Process Lag

From the foregoing discussion on response in temperature measurement it can be seen that there are three types of process lag. These are: Capacity lag, transfer lag, and dead time.[1]

Capacity lag is a generally desirable feature in a steady-state process system, except when it is desired to make a change in the operating conditions. An example of capacity lag would be the thermal inertia of a fluid warmed in a continuous heat transfer system. If the heating medium flow rate or temperature increases, the thermal capacity of the fluid being warmed absorbs some portion of the increased transfer of heat, thus retarding temperature increase in the process system.

Transfer lag refers to the rate at which the supply side of a system can impart energy to the demand, or process side. In heat exchange or in a process tubular heater, transfer lag is caused by the resistance to change rate of heat transfer through the tube metal.

Dead time is a distance-velocity relationship. For example, the temperature sensing element measuring coil outlet temperature of a process heater is some distance downstream of the coil itself. The time required for the hotter — or cooler — liquid to reach the temperature element is called dead time. It is, of course, inversely proportional to flow velocity, and directly proportional to the distance between the process and the measuring element.

Function of Automatic Controllers

It is the job of the automatic controller to receive a signal from an indicating or measuring device, compare this signal with a standard or preset control point, and compute and initiate control action, if required. Depending upon the dynamic response of the process itself and the measuring and control elements in the control loop, several types of controller action may be considered. There are two main groups, (1) those types that have two or more preset control position, and (2) those that impart a continuous range of flow rates in some predetermined relationship to the amount of deviation or error from the control point.[1]

On-off control is included in the first group. The control valve is either open or closed. Obviously, this can result in a great deal of cycling in the process system. One way of compensating for this is to use high and low limits for the controller action so that the valve is neither fully open nor does it completely close.

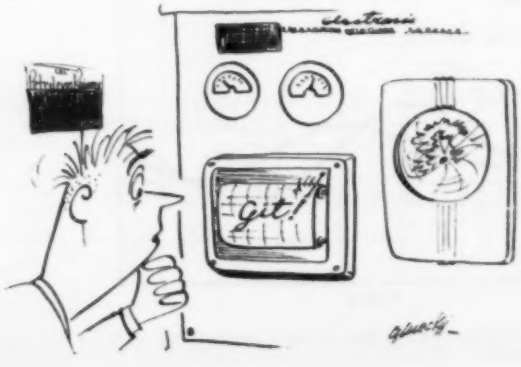
Continuous controller action can be used to obtain smoother, more precise control of the process system. There are several types of controller action from which the best of a given problem can be selected, as follows:

Floating Action
Proportional
Proportional-reset
Proportional-rate
Proportional-reset-rate

Floating action can take one of three forms — single-speed, multispeed, and proportional speed. It is this action that will compensate for a load change in the system. The position of the control valve has no fixed relation to the temperature, but is changed continuously in the proper direction whenever there is a deviation from the control point.

Single speed action means that the rate of valve travel is constant, regardless of the rate of change in the controlled variable. This technique has obvious drawbacks. The multispeed system has high and low-limit contacts, so that the valve will move to another speed if the controlled variable moves outside of a specified range.

Proportional action is a further improvement upon multispeed action, wherein the rate of valve travel is proportional to the deviation of the controlled variable. Note that this action is *not* proportional to the *rate of change* in the controlled variable. Thus, while responsive to a change in the controlled variable and a change in the load on



TYPE OF CHANGE	On—Off	Floating Action Proportional Speed	Proportional	Proportional With Reset	Proportional With Rate	Proportional With Reset & Rate
CONTROLLED VARIABLE						
SLOW	✓	✓	✓	✓	✓	✓
INTERMEDIATE		✓	✓	✓	✓	✓
RAPID		✓	✓	✓		✓
—LOAD CHANGE—						
SMALL	✓		✓		✓	
SLOW	✓	✓	✓	✓	✓	✓
INTERMEDIATE		✓				✓
RAPID						✓
—LAG—						
SMALL	✓	✓				
INTERMEDIATE			✓	✓		
VARIABLE					✓	✓

What control response to use?

the system, the floating action causes considerable cycling, and a relatively low rate of response to a change in the process.

Proportional response overcomes some of the drawbacks of floating proportional action. In this type of control, the valve position is proportional to the deviation of the controlled variable from the control point. But, proportional control alone will not compensate for a load change in the process. Here's why:

A proportional response control system responds only when there is an undesired change in the controlled variable. There is no net change in the valve position once the control point is re-established. If there is a load change, there will be an offset in the temperature of the controlled valve called droop.

Proportional-reset. If we combine the better features of proportional response and floating action, we have, by definition, proportional-reset control. Reset action is imparted by the proportional-speed-floating action, wherein the rate of valve change is proportional to the deviation of the controlled variable and the set point. And, the proportional response minimizes the amount of deviation from the control point. Thus we have a system that will respond to both load changes and deviation of the controlled variable and control point at constant load.

Derivative or rate response can be incorporated into our control system, too. In this action, the valve movement is proportional to the rate of change in the controlled variable. The faster it moves away from the control point, the more the valve will open.

This feature can be included in both the proportional control system or in the proportional-reset action. It will tend to minimize the effects of both process and measurement lag.

What Type of Control Response to Use?

Each additional feature that is built into a controller costs money. It is therefore necessary to analyze the nature of the process system and desired control action, and select accordingly.

Factors to be considered include the nature of the process itself, possible load changes that may be imparted on the process as a whole or its components, and dead time in the system.

[1]J. H. Perry, Editor-in-Chief, "Chemical Engineers' Handbook," McGraw Hill Book Company.
[2]D. P. Eckman, "Industrial Process Control," McGraw Hill Book Company.
[3]G. L. Farrar, "Process Automation," Oil & Gas Journal, Vol. 55, No. 7.

RECENT DEVELOPMENTS IN

Instrumentation & Control Equipment

More accurate measuring elements and electronic systems may help to improve process control

New ideas and techniques in equipment design have paralleled the increasing interest and applicability of automation in the continuous process industries. One of the first and most important of the key developments was the advent of pneumatic or electrical transmission between the measuring device and the recorder or controller.

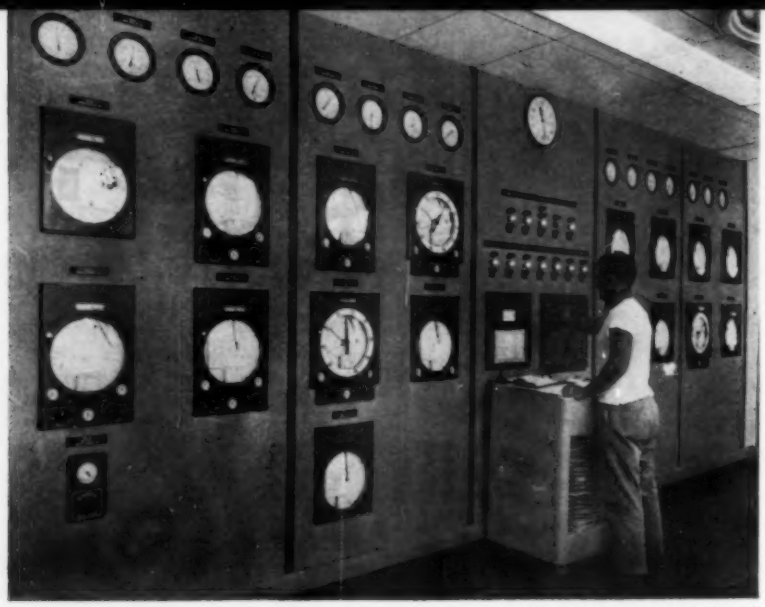
This has made possible the further refinement of the central control room, where data from all parts of the process unit can be brought together, compared, and control action initiated. Use of signal transmission also made it possible to divorce the controller from the recording element, thus permitting faster response in the control loop.

Miniature recorder-controller combinations have reduced the cost of the control panel, and made possible the graphic panel, of inestimable value in operator training and understanding of the process. As Fig. 1 shows, the transition from standard-sized to miniature units has been gradual.

Other significant advances include the increased use of electronic control, new techniques and equipment for continuous analysis of process streams, automatic scanning and logging of process data, and the use of electronic computers to calculate process variables.

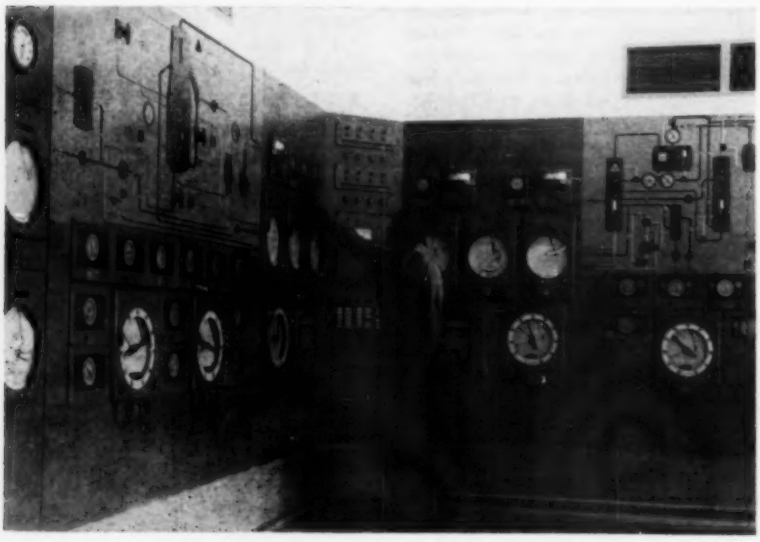
On the foreseeable horizon is the use of electronic computers in the control loop. One company, the Ramo-Wooldridge Corporation, has announced such a unit. A fully transitorized digital computer, it will automatically read process instruments, make the computations required to relate these data to process objectives, determine the proper control actions, and activate process mechanisms or adjust certain set points in supervisory control loops.

Measuring elements or primary elements are the nerves of any control



— Standard Oil Company of California

FIG. 1. Transition from standard-sized to miniature recorder-controllers has been gradual... **Crude unit control room,** above, equipped with standard-sized instruments, built in 1949. **Central control room,** center, for crude distillation and catalytic cracking units. Note the small graphic panels and presence of several miniature recorders. **This graphic panel,** below, put into use this year, uses miniature recorder-controllers almost exclusively.



— Imperial Oil Company, Ltd.

— Cosden Petroleum Corporation

system. There is a constant demand for elements that will have better accuracy, higher reproducibility, and a minimum of lag. There are, basically, two types of primary elements in the control or measuring system. The first type responds to the physical conditions surrounding the element — i.e. temperature, pressure, level, or fluid flow. The second type is activated by the chemical surroundings, usually operating at fixed conditions of temperature, pressure, and flow. Commonly called continuous process stream analyzers, this second group is the subject of a separate article "Continuous Analyzers — Key to Process Automation" found elsewhere in this issue.

Fluid flow meters fall generally into four categories, as follows: *Variable-head* meters include the orifice meter, venturies, and flow nozzles. *Area-type* meters are more commonly called rotameters. *Stream-velocity* meters, which include turbine, ultrasonic, and electromagnetic types, are coming into increasing use, especially for high viscosity service and applications where high accuracy is desired. The fourth group includes the positive displacement type of meter, which can utilize a nutating disk, sliding vane, or piston to drive a totalizing counter.

The electromagnetic meter is, in reality, an adaptation of a turbine meter. A turbine meter simply consists of a rotor that drives a counting mechanism. The electromagnetic meter overcomes the greatest disadvantage of the turbine meter — friction — by means of a small magnet embodied into the core of the rotor. This magnet generates a pulse in an externally-mounted pick-up coil; the pulse is directly proportional to flow, and can be used to activate remote indicating, recording, and control instruments. These units, such as the one illustrated in Fig. 2, are not sensitive to the type of fluid flowing and provide an accurate indication of flow rate regardless of density or viscosity.

The output from this meter can be integrated with the liquid density as measured by a float-type densitometer to give mass flow rate.

Other types of mass flow meters have received considerable attention, too, particularly from the military. Whether or not these instruments will become popular in refining and petrochemical applications remains to be seen. Included in this group is the General Electric Torque Meter and the Maxon Ultrasonic flow meter (available for commercial uses through Fischer and Porter). The torque meter uses a motor-driven, constant speed rotor to give angular momentum to the fluid. This momentum is absorbed by a sec-

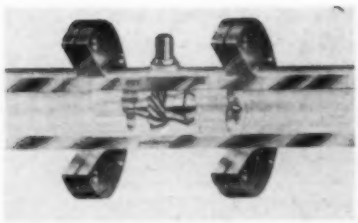


FIG. 2. **Electromagnetic turbine flow meter.**

— *Potter Aeronautical Corporation*

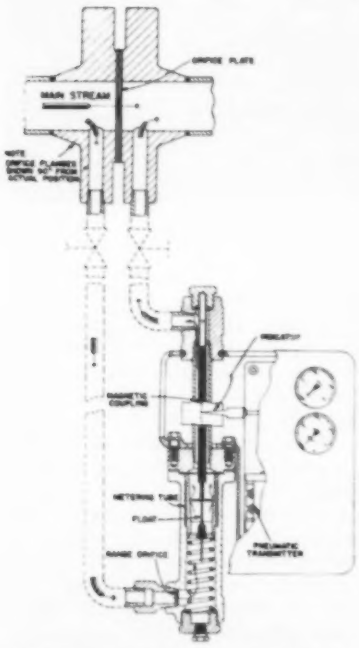


FIG. 3. **Schematic drawing showing operating principle of the kinetic manometer and the operating parts of V/A cell transmitter.**

— *Fischer and Porter*

ond rotor, attached to a spring. The displacement of this rotor, as indicated by a dial meter, is a function of the mass flow.

The ultrasonic meter is based on time required for high frequency wave propagation between a receiver and a transmitter. There are two transmitters and two receivers in the unit, on set pointing downstream (diagonally), the other upstream. The differential frequency (the upstream loop subtracted from the downstream loop) is directly proportional to the fluid velocity.

Density is measured by an ultrasonic transducer that measures acoustical impedance of the fluid. This impedance is the product of the ultrasonic velocity of propagation and the fluid density. The fluid density is therefore obtained by dividing the acoustic impedance by the velocity of propagation, which is proportional to the sum of the two loop frequencies.

A computer section handles these calculations, and gives an indication of the mass flow rate, which is, of course, the product of the fluid velocity (volumetric flow) and density.

An interesting adaptation of the area meter is its use to differential measurement across an orifice. Shown in Fig. 3, the meter measures the bypass flow caused by the differential across the orifice, thus is called a "kinetic" or flowing manometer. The scale is linear rather than square root, and a wide operating range is possible.

Important to measurement of both fluid flow and differential pressure has been the force-balance cell. Not only are these units capable of measuring differential pressure changes as fast as 20 to 30 cycles per second, but also the useful range as compared to the older liquid-filled manometers has been extended many-fold. Greater accuracy at both ends of the measuring scale is also enhanced.

Pressure transducers are available for most commercial applications ranging from very high vacuum up to 25 to 30,000 psi. Two new types of pressure-measuring devices have been recently introduced, both designed to provide extremely high accuracy and to overcome high pulsation errors.

One of these is the Electromanometer, developed by Consolidated Electrodynamics Corporation. Illustrated in Fig. 4, the pressure cell is a null-balance unit. Any movement of the measuring cell is transmitted by a linkage connected to a differential transformer. Voltage output from the transformer is amplified to produce a current that repositions the linkage to zero position. The pressure force and the electromagnetic force are thus at null balance, with the analog output voltage directly proportional to the input pressure and unbalance force. The unit can be used to measure both differential and absolute (or gage) pressures.

The Fischer and Porter "Press-I-Cell" operates on a similar principle. Shown in Fig. 5, changes in pressure are detected by an assembly consisting of capsules (or a spiral) and an armature. When there is a deflection due to pressure change, the armature moves

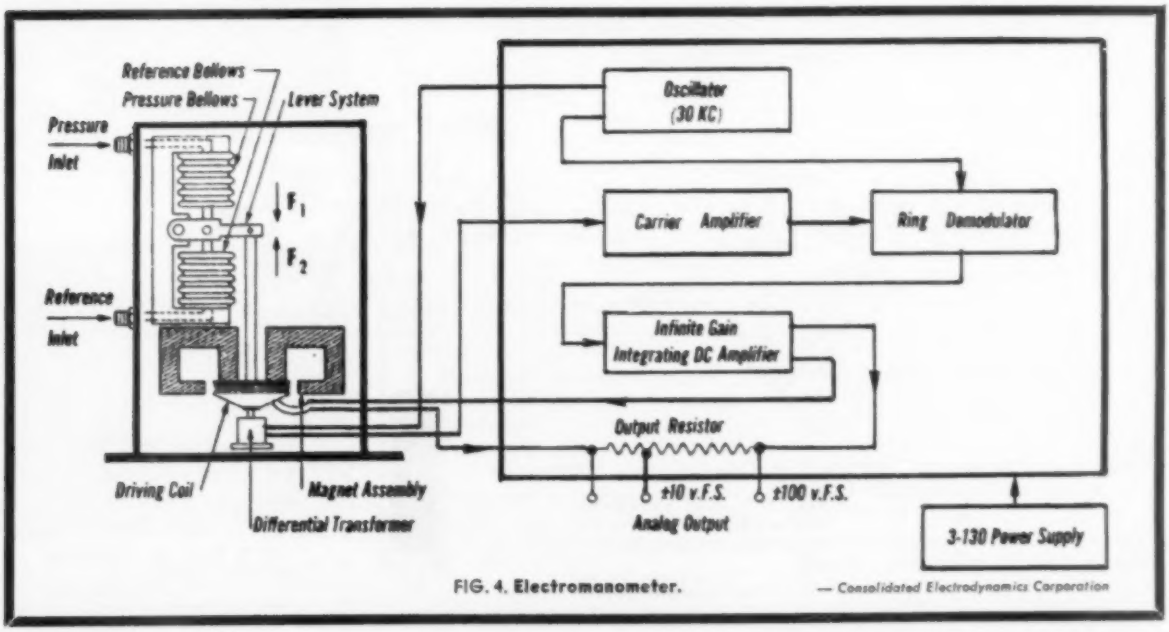


FIG. 4. **Electromanometer.**

— *Consolidated Electrodynamics Corporation*

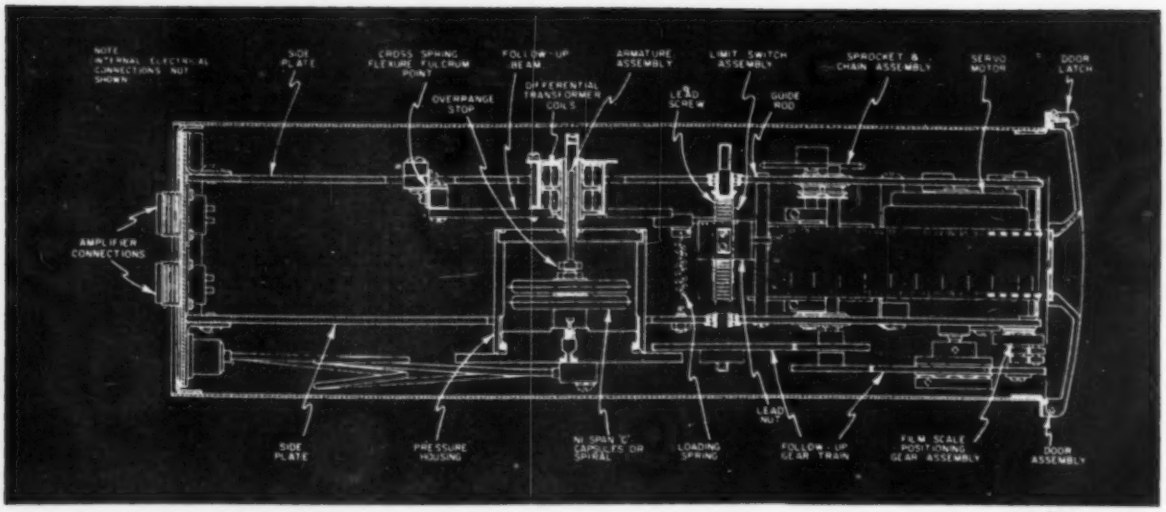


FIG. 5. Direct-indicating electrical pressure cell.

— Fischer and Porter

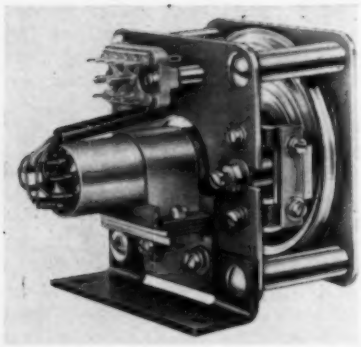


FIG. 6. Pressure transducer that converts a 3-15 psi pneumatic signal to a-c millivolts output.

— Fischer and Porter

within the differential coils, creating an electrical unbalance. An amplified signal is sent to a servo motor which drives a film scale to indicate the pressure, and repositions the differential coils to a balanced condition. Both differential and absolute pressures can be measured with ranges from 0-4 through 0-1000 psi available.

Pressure transducers are also used to convert a pneumatic signal to an electronic signal. One such unit, recently made available and shown in Fig. 6, converts a 3-15 psi signal to a-c millivolts directly proportional to the pneumatic input.

Temperature measurement is an area of relatively slow progress, with very few developments that aid in overcoming the measuring lag inherent in most temperature systems.

At present, the onus is on metallurgists, who have yet to develop a thermocouple that can be directly immersed in most process streams. Such a unit would eliminate the lag caused by thermowells. Perhaps part of the answer can be provided by light, high strength alloys that could be used to make thin-walled wells.

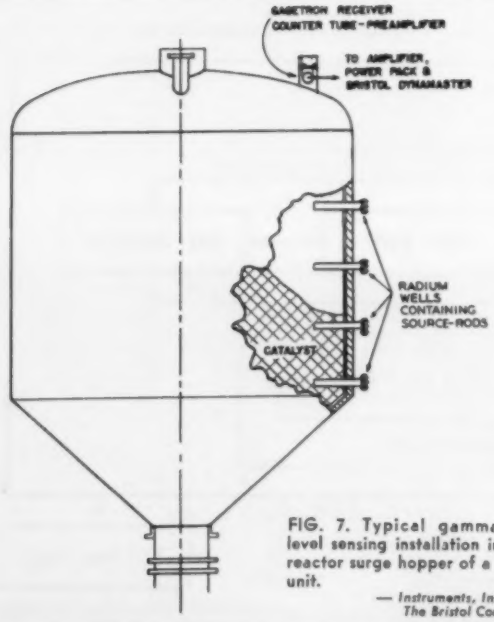


FIG. 7. Typical gamma-ray level sensing installation in the reactor surge hopper of a TCC unit.

— Instruments, Inc. and The Bristol Company

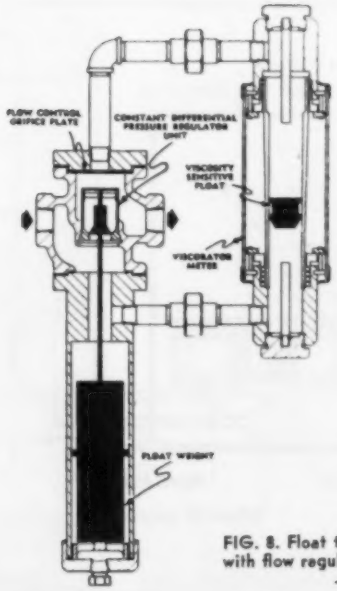


FIG. 8. Float type viscosimeter with flow regulator.

— Fischer and Porter

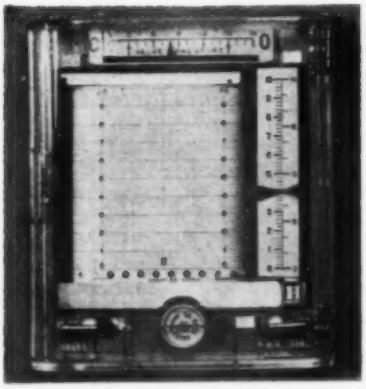


FIG. 9. Miniature pneumatic recorder unit.
— Minneapolis-Honeywell Regulator Company

Liquids and solids level measurement has been an area of intense development during the past few years. The new units use capacitance, conductivity, sound wave propagation, and radiation to determine liquid or solids level.

Electronic measurement of liquid level has been especially helpful in automation of tank farm operations. One unit, the Gilbarco tank gage, uses a sensing element on the end of a perforated tape to detect and report level. A one-tube transmitter supplies r.f. signals to the sensing element, which is suspended in the liquid 1/16 in. Return signal strength depends upon the amount of submergence; an amplifier-receiver unit keeps this signal constant by control of a servo motor powering the tape wind-up. The drum position is telemetered to a central location where the signal is transposed to make readings in feet, inches, and fractions of an inch, down to sixteenths.

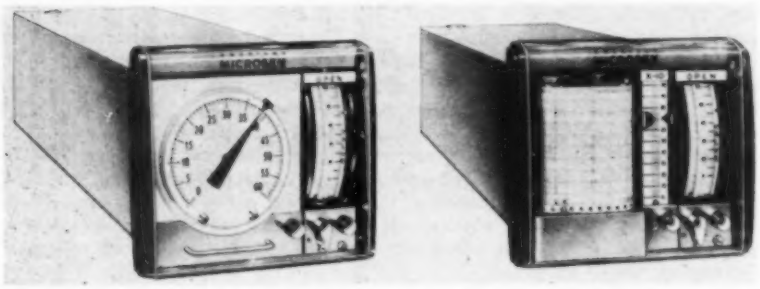


FIG. 10. Electronic controllers, showing both indicating and recording types.
— Manning, Maxwell, & Moore

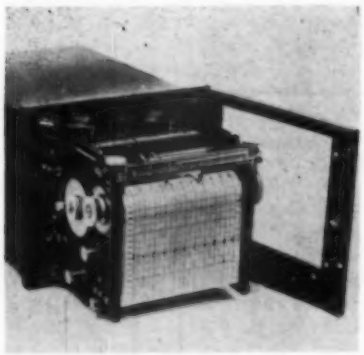


FIG. 11. Two-pen recording potentiometer with 5-in. strip chart.
— Westronics, Inc.

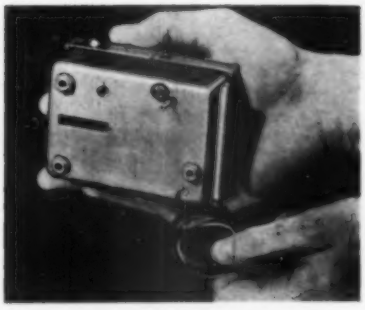


FIG. 12. A linear integrator, designed for continuous operation with strip charts and other low force-low torque devices.
— Librascope, Inc.

A resistance thermometer is usually incorporated into the system, too. The level and temperature signals can be fed through an electronic computer that integrates these data with pre-set tank strapping and fluid characteristics, thus calculating a complete inventory. In one new refinery, 88 tanks are so equipped, and a complete inventory is automatically logged every eight hours, reporting tank number, level, tank fluid, fluid gravity group, temperature, time, and barrels contained corrected to a standard temperature.

The capacitance-type level gages use an insulated electrode suspended in a vessel containing either liquids or solids. The capacitance between the electrode and the walls of the vessel is a function of the submergence in the liquid or solid. The unit is calibrated by measuring capacitance when probe is completely immersed and surrounded with air (or another gas). Intermediate levels can be determined by comparing measured capacitance with capacitance obtained at both ends of the scale.

In one application, a capacitance unit was used to replace conventional gage glasses in sulfur dichloride tanks. These gage glasses usually became caked and coated with sulfur dichloride deposits after a few weeks use, and it was necessary to empty the tank to clean the glasses. The capacitance unit has been in use for more than a year and has not required maintenance, has given accurate level indication. Since the capacitance probe is plastic-coated, there are no corrosion problems.

Radiation-type level gages have found increasing use in measuring catalyst level in Thermofor Catalytic Cracking unit reactor surge hoppers. The instrument is also applicable to measuring catalyst level in fluid reactors and regenerators, as well as in storage hoppers.

In such installations, gamma-ray sources (radium) are mounted in the tank in such a way as to not lie directly over one-another in line-of-sight with a Gieger counter tube mounted in the top of the vessel. The counter thus totalizes radiation projected by all of the sources. The total radiation as measured by the Gieger counter is a function of the number of uncovered elements as well as the depth of material lying above the covered elements. To compensate for this non-linear relationship, the radiation sources are supplied calibrated in terms of number of impulses produced per second. The strongest source is placed at the bottom of the vessel, with progressively weaker elements above it — the weakest at the top, nearest the counter, of course.

Ultrasonic measurement of liquid level can either be an exposed or immersed system. In the immersed system, a transducer mounted in the bottom of the tank transmits high-frequency waves to the surface of the liquid, with re-elected pulses re-triggering the transmitter. Electronic instruments measure the time required for "bounce-back," which is a function of liquid depth. The system is standardized by a transducer that transmits a signal horizontally across the tank, where it bounces off a fixed point, and returns to a second receiver.

In the exposed system, the same principle is used. One transducer is mounted in the top of the vessel bounces signals off the liquid surface, while the other transmits through the gaseous medium above the tank fluid, to a fixed point on the opposite side. In both systems, the time required for signal transmission and receipt is a function of liquid level.

Continuous measurement of fluid density, specific gravity, and viscosity is becoming increasingly important. Fluid density and specific gravity are

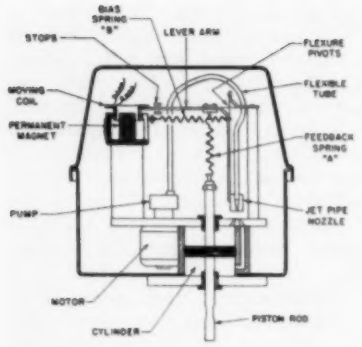


FIG. 13. Cutaway schematic drawing of an electrohydraulic valve actuator.

— *Askania Regulator Company*

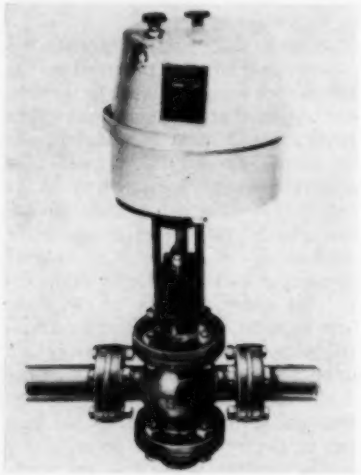


FIG. 14. Electrohydraulic valve actuator designed for use with low-level a-c or d-c signals can be used for valves having $\frac{1}{2}$ to $1\frac{1}{2}$ in. stroke, requiring less than 200 lb thrust.

— *Askania Regulator Company*

frequently found in product specifications, and are also important in control systems where weight balance is an important factor. Viscosity specifications must be met in lubricating oils and heavy fuel oils and continuous, accurate viscosimetry is one key to automatic control of blending these products.

There are several types of continuous viscosimeters available. The rotational type employs a spindle that is submerged in the fluid. The spindle is rotated at a constant speed by a synchronous motor. A hair spring and gearing arrangement is used to measure torque exerted against the spindle by the fluid, with the torque being proportional to viscosity.

Capillary viscosimeters are based on the principle that viscosity is directly proportional to pressure drop across a capillary at constant flow rate. This unit, while successfully employed by at least one petroleum refiner, is extremely sensitive to minute changes in the controlled rate of flow and the temperature of the fluid.

The float type viscosimeter illustrated in Fig. 8 is commonly employed in the refining installations. The unit shown uses a weighted valve body that is designed to maintain constant flow through the viscosity measuring tube. Another variation on the float type viscosimeter is use of a positive displacement pump to maintain constant flow of the sample. The unit illustrated is an indicating instrument, but can be modified for recording-controlling functions by addition of a conventional electromagnetic pickup, identical to that used for recording and remote indicating rotameters.

The plunger type viscosimeter is quite similar to the float type unit. A long, cylindrical plunger is arranged concentrically within a uniform bore tube. A chamber above the narrow annulus accommodates a heavy (about 3000 grams) weight mounted on the plunger. Constant flow is maintained through the unit; the fluid enters from the bottom of the instrument, and the viscosity is a function of the float rise. This particular unit is especially adapted for viscosity measurement in high regions, above 400 poises.

The Ultra-Viscoson (Bendix Aviation) continuous viscosimeter uses a thin alloy blade to which ultrasonic waves are applied. The rate at which the vibrations are damped by the surrounding fluid is a measure of viscosity. Temperature compensation can be provided in the system, which uses small analog computers to provide a signal to the recorder-controller unit.

There are many types of fluid density and specific gravity units designed for continuous measurement. Displacement-type units use a float with its submergence a function, of course, of liquid density, with level being held constant. The chain-balance float density indicator and recorder uses a bob that is attached to a chain. The other end of the chain is fastened to the side of the flow vessel. As density increases, the bob rises, supporting more chain. A rod attached to the top of the bob passes through an a-c coil, with the voltage output being a function of the liquid density.

The bubbler-type densitometer measures the amount of pressure required to overcome a given head of sample as compared with the pressure needed to displace a similar head of water.

Since specific gravity is merely the density of the sample fluid corrected to 60 F and divided by the density of water at that temperature, instruments used to measure density can be modified to show specific gravity. This can be done by means of a 60 F temperature bath for the sample, or by computation, if the expansion characteristics of the sample fluid are accurately known.

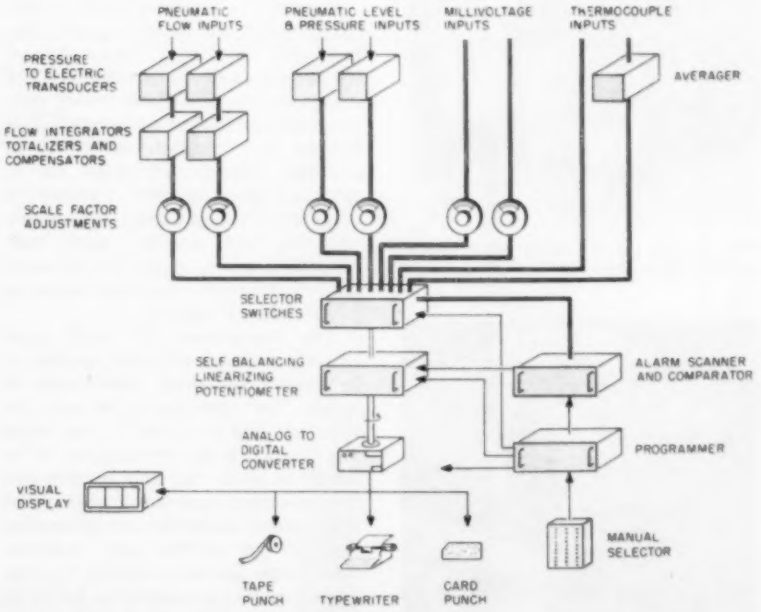


FIG. 15. Block diagram of an automatic data logger.

— *Minneapolis-Honeywell Regulator Company*

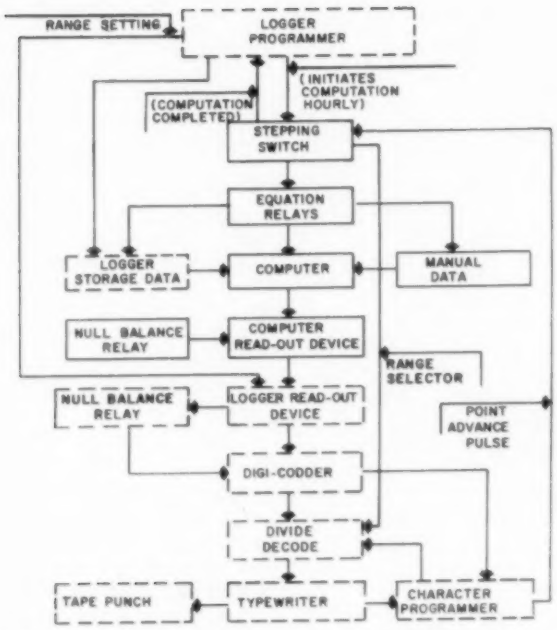


FIG. 16. How logger and computer functions are coordinated.
— *Fischer and Porter*

Recorders and Controllers

Two basic trends have influenced recording and controlling elements during the past five to seven years. First of these is miniaturization, and the second is the increasing use of electronic control, rather than pneumatic.

Several advantages have been cited for the miniature units, the first of which is reduced panelboard space requirements, leading to reduced board cost, and — possibly smaller control rooms. Miniatures have been so popular since their introduction that most new developments are incorporated in them rather than in the large, rectangular-cased units. Consequently, miniatures have a wider range of settings, the best control circuit design, and higher capacity relays. Interchangeability of components is also possible. Thus, the units can be taken to a shop for repair, and replacement part inventory is minimized.

A miniature-sized pneumatic recorder is illustrated in Fig. 9. Typical of many of the units now available, the recorder and indicator chassis are interchangeable without process downtime . . . the pressure gage and the pressure regulator are part of the case. The controller for units such as the one shown can be mounted behind the recorder, on the panelboard, or at the control valve, depending on what hookup is most advantageous.

An electronic counterpart of this unit is shown in Fig. 10. Extremely flexible in application, changeover from indicating to recording can be done "on-the-fly." Similarly, changes can be made from proportional action to proportional plus reset action, and from slow reset to fast reset.

Miniature recording potentiometers such as the one illustrated in Fig. 11 considerably reduce panelboard space requirements. The unit shown has a five inch chart with two pens operating margin-to-margin. The amplifiers are transistorized, requiring less volume than vacuum tube amplifiers.

Linear integrators (Fig. 12) that are specifically designed for strip chart recorders make possible direct or remote reading in any instrument or system where continuous integration, area or average, is required.

Final Control Units

Final control elements are of two basic types, pneumatic and electronic. The electronic units are further divided into three groups — all-electric, pneumatically-operated valves with electropneumatic relays, and electrohydraulic operators.

All of the electronic actuators have one element in common, the moving coil. The diagram showing principle of operation for an electrohydraulic actuator (Fig. 13) will serve to illustrate how the moving coil operates. The coil is suspended in the air gap of a permanent magnet. A change in the signal from the electronic controller will cause the coil to try to move further into or out of the magnetic field. This force can either be applied in a null-balance system (feedback spring) or to change mechanical position.

In the all-electric actuator, the force exerted by the moving coil is counter-balanced by a feedback spring which is expanded by movement of the valve stem. Any movement of the moving coil that is caused by change in signal output from the controller displaces the core of a differential transformer. An amplifier in turn energizes a reversible electric motor that operates until the spring balances the input signal and the system is again in balance.

Electropneumatic systems use the moving coil to position a pilot valve and feedback diaphragm pressure regulator that in turn operates a conventional pneumatic-powered valve.

The electrohydraulic operator, illustrated in Fig. 13 and 14, uses the force exerted by the moving coil to position to jet pipe nozzle. In operation, oil is pumped by a self-contained pump through the jet pipe and discharged at two closely spaced orifices which are connected to opposite ends of the cylinder. When the jet pipe is centered, pressure differential across the piston is zero and no action occurs.

When the moving coil causes the jet pipe to move, a pressure unbalance is created, and the force of the oil discharging from the jet nozzle will favor one of the orifices, causing the actuating piston to move, repositioning the valve.

A feedback spring connected to the moving coil linkage equalizes the forces acting on the jet nozzle as it reaches its new position. The jet pipe then returns to a null position and the pressure differential across the piston is again balanced.

Pneumatic vs Electronic Control

Flexibility of the electronic control system is one of its greatest advantages, especially in light of the increasing trend toward data reduction, logging, and computing systems in the control loop. The electronic signal can be handled directly by these systems, eliminating the need for a pneumatic-to-electronic transducer.

The above is probably the least controversial in the hotly discussed pneumatic-electronic debate. Other major points of discussion are cost, maintenance problems, controller response, and the final control element.

Components of the electronic control system are more expensive than their pneumatic counterparts. Whether this will be a permanent situation depends on just how well the techniques of mass production will further reduce costs. But, tending to equalize the situ-

ation is the fact that the transmission link (wire) for electronic system is cheaper than pneumatic tubing. Thus, the more remote the control room is from the process operation, the greater will be the advantage for the electronic system.

Maintenance problems with electronic systems have been few, and re-education of instrument men to handle this system is not difficult. But, when there is a power failure, control is lost immediately. Pneumatic systems can be installed with reserve capacity and will close down gradually.

Response of the electronic control system is more rapid than that of a pneumatic system. Whether this is an advantage or not depends upon process "external" factors. In many instances, the process lag and measurement lag — in temperature systems, especially — is far greater than the control response lag, thus negating this seemingly apparent advantage for electronic control. Electronic systems do have a clear-cut advantage when it comes to remote-location control-pneumatic systems are generally limited transmission distances of not more than 500 ft.

One of the greatest disadvantages in electronic control systems is the lack of standardization in signal ranges. The 3-15 psi signal range is virtually universal in pneumatic control, but there is no corresponding similarity in electronic signals. This may come, however, as electronic control comes into more universal acceptance and utilization.

Data Loggers and Scanners — Another Step Forward in Automation

More and more refiners are coming to the realization that automatic logging of process data is not an end in itself. While one spokesman recently said that a logger that merely prints out data "must be justified primarily on the basis of replacing a hand-written log sheet with a typed log sheet," there are many other considerations that also enter into the picture.

Data loggers are capable of performing many valuable functions in addition to eliminating need for a hand-written record. Inherent in their use are these advantages:

1. More accurate reporting of process data, with better time relationship.
2. Automatic totalizing and averaging of data on an hourly or daily basis.
3. Automatic calculation of flow rates at corrected conditions of pressure, temperature, etc.
4. Availability of data recording during upset periods.
5. Presentation of data in machine language, in the form of punched cards or tape for direct feeding into a computer for further calculations.
6. Direct integration with analog or digital computers to calculate key process variables.
7. Continuous scanning of process data points when not actually printing out the data log.

The last-stated advantage is one of the most important in present-day installations. An automatic data logger can scan 50 to 100 points in a minute's time, and can be built to actuate an alarm system if predetermined limits are exceeded. The operator can then punch a button that will cause the logger to print out all off-normal points, thus determining the cause of the alarm, if there is not an alarm signal specifically installed for the point in question. Or, the unit can be arranged to automatically print off-normal points.

Integration of an analog computer with a data logger will soon become a reality. Esso Standard Oil Company S. A. is incorporating a computer with a logger on a catalytic cracking unit that will calculate 11 operating guides, logged at the end of a read-out cycle. These guides include such information as carbon burning rate, catalyst circulation rate, corrected conversion, catalyst to oil ratio, and other important, derived process variables. In addition, the logger will print out 101 temperatures, pressure, flows, etc., hourly or more often if desired.

Electronic Computers in Engineering and Research

Applications are limited only by human imagination

To strike a balance between experimental research, engineering, and the refining process itself, more and more refineries are turning to electronic computers.

At one time, refining was based on simple transformation. Today, however, a growing variety of crudes must be refined into a greater variety of commercial end-products, adequate to keep up with consumer demand.

Research has obviously moved into a position of strategic competitive importance. But the time-lag between the start of a research project and commercial exploitation of its results is often too great. Refineries know they must both expand their research activity and close the gap between it and actual production.

They have found three principal functions of the refinery computer — mathematical model refinery operation, simulated experiments, and data reduction. These functions lead to such projects as improving catalytic cracking processes, octane and vapor pressure blending, alkylation, reforming, and tetraethyl lead addition.

Photos and material provided by ElectroData, Division of Burroughs Corporation.

Equational Building

One of the more striking examples of speeding research and increasing accuracy through electronic data processing, and at considerable cost-saving, is the "building" of a refinery with mathematical equations.

In this equational construction of a refinery, the computer is set up for a research-manufacturing balance by the use of a set of principals for determining the path through the refinery of every barrel of every stock, and for determining the yields from each operation for each stock processed.

A portion of a Datatron 205 electronic data processing system. From left, in rear, are the single magnetic tape storage units, multiple Datafile magnetic tape unit, magnetic tape control unit, floating point, and central computer. In the foreground is the control console, including an electric typewriter, high-speed tape punch and photoelectric reader. — *ElectroData, Division of Burroughs Corp.*

For every process operation in the refinery, the computer operator must have a set of directions to name which stocks are to be processed and how much of each is to be used.

In solving a refinery problem . . . whether it concerns future plans or day-to-day operations . . . mathematicians first analyze the problem and break it down to a series of simple numerical steps. This is termed programming.

Then, using a keyboard similar to that of a typewriter, the technician punches the problem's numbers and commands as perforations on paper tape. This procedure can involve hundreds of specific instructions for the computer.

The input tape is fed into the computer. Its perforations are translated photoelectrically into magnetized spots on a rotating drum within the computer. One of these memory loads can control thousands of steps in the overall equation. When even more number (representing units or other factors in the process being computed) or commands must be stored, the computer's magnetic tape unit comes into play. A single reel-type tape unit can hold up to four-million digits for use by the computer.

High-speed printing facilities or punched cards are used to accept the computer's answers.

Master Program

A master program unites the various operations — catalytic cracking, alkylation, etc. — into a mathematical model of a complete refinery. This plan also simulates the piping between units and contains the logic for making decisions in the event alternatives arise.

Since a refinery operating plan is not static, the computer program is flexible enough to allow for sudden changes. This flexibility is achieved through the use of sub-routines, or groups of commands. As an example, determining how a catalytic cracking unit can be loaded to capacity with the available charge stocks requires using a group or block of computer commands. One block of commands decides which stocks and how much of each will be charged to the unit, removing the amount charged from the list of stocks available to other units. Another block calculates the yields of products on the basis of a correlation of yields with operating conditions.

This correlation can range in complexity from a specification of fixed percent yields to a complete temperature-residence time-catalyst activity-stock type-recycle ratio correlation of the reaction kinetics.

All the blocks in the chain of computer commands are linked with another block called the directive routine. This program tells the computer which block to use, and in what order.

A refinery program involves thousands of input commands, but achieving the balance through electronic calculations may take only three minutes. The computer's magnetic drum stores up to 40,800 digits, any one of which can be located on the drum in a few thousandths of a second.

It takes the computer just 1/400 as long as manual calculation to get the answer to the problem of what finished products will be gained by charging a set amount of barrels of a varied number of crudes under specified operating conditions.

Speedup Techniques

Data reduction ranks as one of the chief uses of the computer in refinery operations.

Data gathered at a refinery or chemical plant is teletyped to the research center. The message is automatically converted from the TWX machine's tape to cards fed into the computer. The Datatron processes the cards in milliseconds, the information is reconverted to TWX tape and the answer teletyped back to the point of origin, saving what could amount to weeks of slide-rule labors.

Statistical methods — simulated experiments — are being employed to reduce the time and amount of costly experimental work necessary in developing new processes by showing how the maximum amount of useful data can be obtained with a minimum number of experiments.

Finding the exact blend of crude oil components which will produce a certain amount of premium and regular gasoline at minimum cost is a typical computer simulation application. Numerical values are assigned to the process variables and constants. These then are manipulated to establish relationships between cost and different blends.

The functions thus derived enable the computer to vary the proportions, together with octane number, vapor pressure, sulfur content, etc., and provide an answer showing which blend will yield the maximum profit.

In determining the correct refinery balance, through the multiple factors involved, as much as $2000 a day may be saved.

Multiple Workload

Other jobs to which the computer can be put to work include assessing equipment performance, equipment design, determining future behavior of oil reservoirs, hydrocarbon separation, evaluation of thermodynamic data, geophysical properties, and quality control.

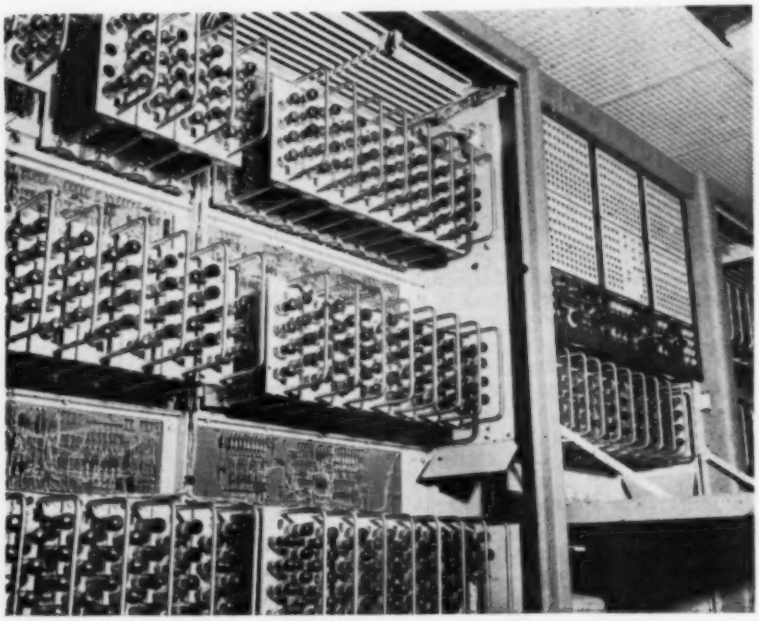
The computer can be used to determine whether pressure, volume, fluid-viscosity, and temperature relationships now generally accepted can be locked into a scheme of inter-relations.

It can be used to calculate the relationships between porosity, composition, grain size, and other characteristics of oil sands.

With Datatron, a solution to a 50-stage fractionator can be produced within two hours. A manual solution might take up to three months, and the accuracy wouldn't approach that of the computer.

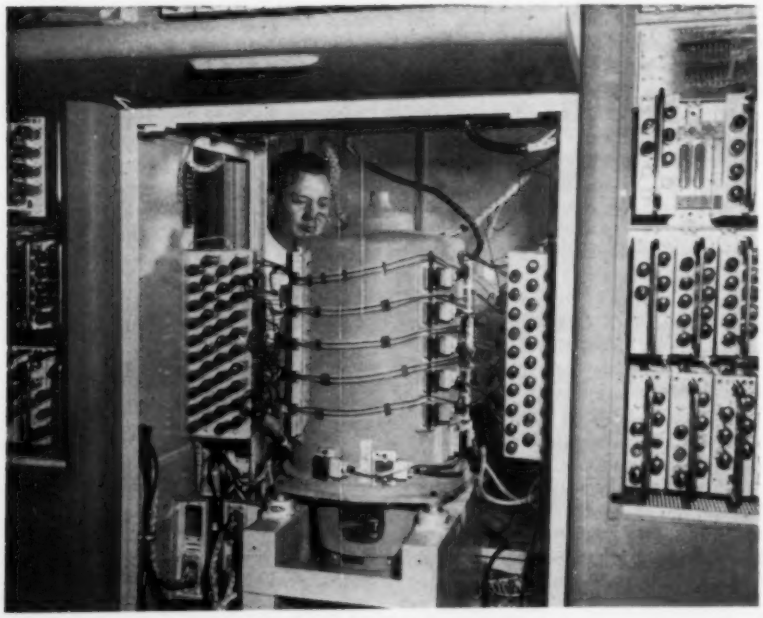
The design of absorbers is a problem simply and accurately answered with the computer, despite the complicated network of intercoolers, varying vapor rates, and absorbing effect of heavy components in the feed. The computer solution is a series of passes down the column for different assumptions of the overhead composition until the calculated vapor to the feed step equals the absorber feed.

With reboiled absorbers, revisions in the product streams are made by comparison of the vapor streams at the feed step as calculated from both the overhead and the bottoms product. Each step is computed by trial and error. A step temperature is assumed and a corresponding heat balance is made until a temperature is found which will satisfy both heat and material balances.



Computer doors opened to expose pull-out tube units and circuitry, with control panel and register units at the right.

— ElectroData, Division of Burroughs Corp.



A magnetic memory drum, which stores 40,800 digits as electronic impulses on magnetized drum inside the steel case.

— ElectroData, Division of Burroughs Corp.

Human Reasoning

It takes human brains to operate electronic computers. Before the computer can calculate a mass spectroscopic analysis in 20 seconds, it must have the problem programmed — one might term it "reasoned" — in detail.

The men who use electronic data processing sum up its advantages as follows:

Speed. The ability to get the answer quickly is extremely valuable in terms of increased production or faster construction.

Reserve. Computer technicians act as an effective reserve, helping design and operating personnel who find themselves temporarily overburdened.

Precision. The computer can calculate problems that a man working with a slide rule could never hope to approach in accuracy.

Morale. Use of the computer heightens morale because it frees design groups from tedious calculations, allowing them the time to give more thought to overall design problems.

A finalized advantage may be said to be the time-trimming of the step between research and manufacturing, thereby getting the product to the consumer at the lowest cost and highest quality just as rapidly as the demand builds up. ★ ★ ★

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CONTINUOUS ANALYZERS

Key to Process Automation

Henry J. Noebels
Manager, Application Engineering, Process Instruments Division
Beckman Instruments, Inc.

CONTINUOUS stream analyzers are, in effect, small, highly specific automatic laboratories designed to provide primary analytical information of the required degree of accuracy and reliability for optimum process operation. These instruments, properly engineered into plant streams, open entirely new concepts and possibilities in process instrumentation.

Since their inception, continuous processes have been monitored and controlled with instruments measuring mainly temperature, pressure, flow, and level. These properties, in most instances, are not direct functions of component concentration. Thus, processes instrumented in this manner are controlled through the measurement of *secondary* variables. The control engineering, in these instances, is based on the inference that the unit will produce specification material in an efficient manner as long as pressures, temperatures, flows, etc., are held constant. In some processes, where yield and quality are not critical, this method of operation is adequate.

In the majority of the more complex processes, however, this "inferential" control is not economically sufficient. The old expression, "nothing is constant but change," is most certainly true. Processes are dynamic — changes in feed composition, impurity levels, catalyst activity, equipment efficiency, and environment require frequent resetting of control points. In order to detect these conditions and determine the magnitude of change required in control point setting, another operation must be incorporated — laboratory quality control at the process unit.

The logical solution to this problem is to utilize modifications of the physical analytical methods that have been thoroughly time-tested in the control laboratory. Automatic continuous stream analyzers based on these physical methods are available. A great deal of time and effort has been expended on the development and application of these analyzers to insure the economic practicability of their use.

Considerations for Instrumenting

End-point of continuous stream analyzers are usually applied to the following five basic streams in a process or unit operation.

1. Feed streams to the reactor;
2. Product streams from the reactor, as a measure of conversion efficiency;
3. Recycle streams;
4. Absorber or scrubber exhaust streams;
5. Final product streams.

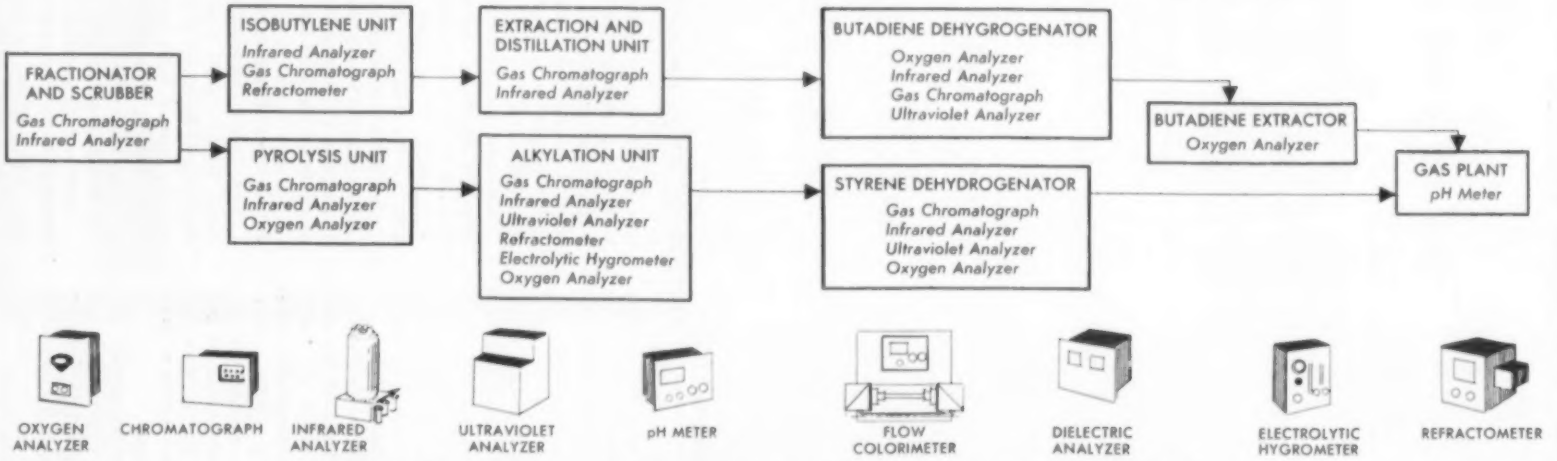
Since almost every unit operation in a process has at least two of these streams, the problem of where and when to instrument might at first seem to be somewhat confusing. Actually, this should not be the case. Continuous analyzers should be considered only in those areas where their use can be justified. The exact mechanism of justification at times can be subject to some debate. Generally the justification is based on payout time. The maximum payout time is usually considered to be two years in both the petroleum and the chemical fields. Petrochemical plants seem to have little difficulty in their justifications in this regard; there are reports of some instruments being paid out in a matter of days.

Payout, in most instances, is based on improved yield or efficiency, higher quality material, increased capacity, lower capital expenditure in storage and blending equipment, and overall lower processing costs. In some instances, the payout is based on lower labor cost, although this is seldom the deciding factor, since most operations are designed for efficient operation with a minimum of labor. In a number of cases, payout has been based on the savings resulting from greatly decreased laboratory costs. Frequently, reports are made showing a saving of $35,000 to $50,000 per year per instrument in laboratory expenses.

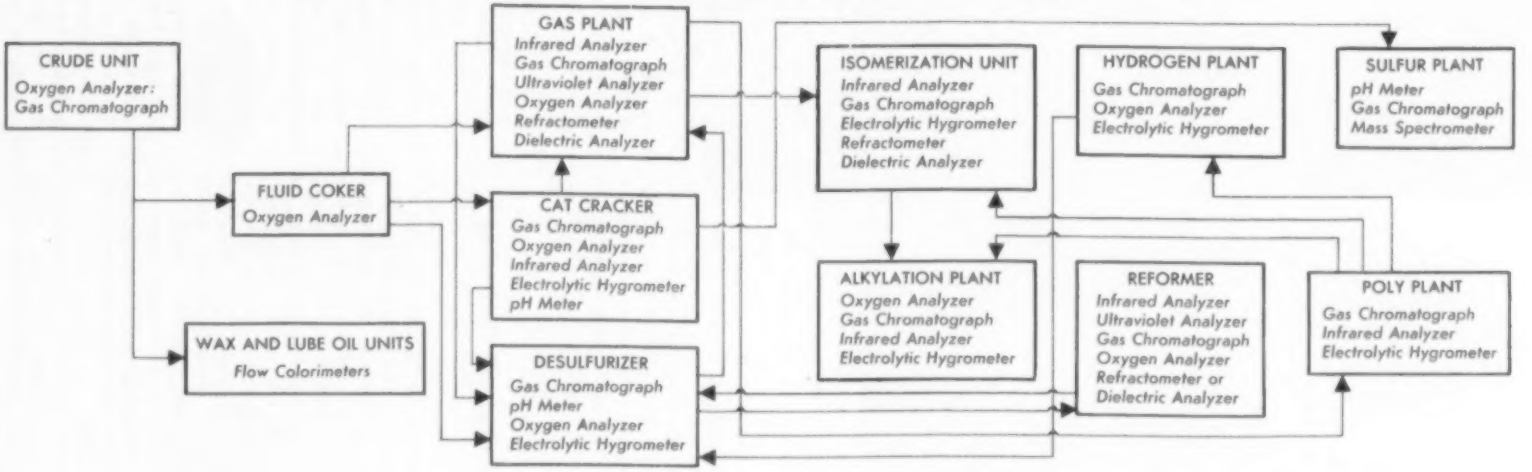
A basic consideration that should be recognized is that the instrument must be competently application engineered into the system. In other words, it should be designed for the specific job it is to accomplish, located exactly at that point of the process where the information as to stream composition is needed, equipped with the proper sample handling system to enable the instrument to operate continuously, and properly scheduled for preventive maintenance.

It is a recognized and accepted fact, in the major design groups, that the best time to instrument is when the plant is on the drawing board. This is

PROCESS EQUIPMENT & ANALYZERS FOR SYNTHETIC RUBBER PLANTS



PROCESS STREAM ANALYZERS FOR REFINERY OPERATIONS



Characteristics and Cost of Continuous Stream Analyzers.

	Infrared	Gas Chromatography	Ultraviolet	Electrolytic Hygrometry	Flow Colorimetry	Refractive Index	Dielectric Constant	pH and Direct Ion	Mass Spectroscopy	Oxygen
1. Stream conditions	gas, vapor, liquid	gas, vapor	gas, vapor, liquid	gas, vapor	gas, vapor, liquid	liquids	liquids	liquid slurry, gas & vapor w/scrubber	gas, vapor	gas
2. Specificity & concentration range	specific 0–50 ppm 0–100%	highly specific 0–1% to 0–100%	moderately specific 0–ppm 0–100%	specific for water 0–1000 ppm	generally specific 0–ppm 0–100%	non-specific 0–5 0–100%	non-specific 0–1% 0–100%	specific ppm to percent range	specific ppm to percent range	specific 0–5% 0–100%
3. Complexity of stream	moderately complex stream	very complex	2 to 5 component stream	complex	moderately complex	binary or pseudo binary	binary or pseudo binary	highly complex	complex	complex
4. Sample handling	critical	critical	critical	necessary but not complex	necessary but not complex	not critical	not critical	not critical	extremely critical	necessary
5. Operator attention factor	1 hour per 24 hour day	1 hour per week	1 hour per 24 hour day	1 hour per week	1 hour per 24 hour day	1 hour per 24 hour day	1 hour per 24 hour day	0.2 hour per 24 hour day	½ to 1 operator per shift	0.2 hour per 24 hour day
6. Service factor	4 hours per week	4 hours per month	4 hours per week	4 hours per month	4 hours per month	4 hours per month	4 hours per month	1 hour per month	8 hours per week	4 hours per month
7. Maintenance Simplicity	simple to moderate	simple	moderate	very simple	very simple	simple	moderately simple	simple	very complex	very simple
8. Instrument cost (in thousands)	$3.5–8.0	$3.5–8.0	$2.0–3.5	$0.8–1.5	$1.5–2.2	$3.5–6.0	$2.0–4.5	$0.4–2.5	$5.0–30.0	$0.7–2.5
*9. Installation cost and sample system (in thousands)	$1.5–3.0	$1.5–5.0	$1.5–2.0	$0.3–1.5	$0.5–1.5	$1.0–2.0	$1.0–2.0	$0.5–1.5	$5.0–10.0	$0.3–2.5
10. Approximate number on process streams	over 1000	over 100	50	over 300	over 500	100	100	thousands	25	thousands
11. On control	Yes	Yes	Unknown	Yes	Yes	Yes	Yes	Yes	No	Yes

* Estimated average cost for installation by plant personnel with purchased sample systems. Figures include recorders, where necessary, but are exclusive of control systems.

the stage where the application engineering staff of the stream analyzer manufacturer, working in conjunction with the design group, can show appreciable savings in plant cost. In some instances, the savings effected in decreasing the size of holding, blending, and storage facilities alone pay for the instrumentation several times in the course of a few years.

Monitoring and Controlling

Initially, continuous stream analyzers were installed as monitoring instruments. Later, as their reliability and performance became appreciated through experience, the instruments were used for control. Mode of control varies with each type of instrument. In pH and flow colorimetry, for example, the instruments are generally used in direct control systems. Infrared, gas chromatographs, and refractometers, on the other hand, are usually engineered into cascade control systems. Actually, no blanket statements or recommendations can be made; each application or problem must be treated individually.

Control engineering has received a great deal of attention of late, especially in the journals dedicated to this subject. But, the highly mathematical approach to the analysis of control systems has a definite tendency to discourage design engineers. Although this approach is extremely valuable and, in fact, necessary in many instances, it is responsible for creating definite wrong impressions concerning the supposed rapidity with which continuous stream analyzers should operate.

For instance, many articles report time constants of the reflux loop of a large column to be in the order of 30 to 50 seconds. These figures are correct for columns that are being controlled by pressure and/or temperature. Since continuous analyzers can control on the basis of stream composition, it is this factor, and not the pressure or temperature of the unit, that is of importance. Since composition does not usually change as rapidly as pressure, it is logical to assume that different modes of control can be employed. But, where the residence time of the material in the reactor is short, this logic does not apply.

Although continuous stream analyzers will always be used in single loop control systems, the future definitely will show an increase in the number of these instruments used in multiloop systems in conjunction with a computer. Several of these analyzers can supply information to a computer, which, incorporating other process information, will calculate the correct reset of the numerous control points in the various control loops of the process. No doubt the computer will also be provided with information relative to general plant economy, sales prices, markets, etc., to allow the process to be optimized relative to dollars rather than yield.

The major factor to be overcome before this degree of controlled operation can be realized is the absolute determination of transient and steady-state process dynamics, and the reduction of these factors into usable mathematical terms. This principle is to be investigated in at least three separate processes in the near future.

Application Engineering

What type of instrument should be used? Where should it be installed in the process? How can it be engineered into the system? What information can the instrument be expected to furnish, to what degree of reliability? How can this information be used for control?

These are the questions that arise in the mind of the interested plant operator. They must be satisfactorily answered in order to allow a sound decision to be made, based on the significant economic benefits of instrumen-

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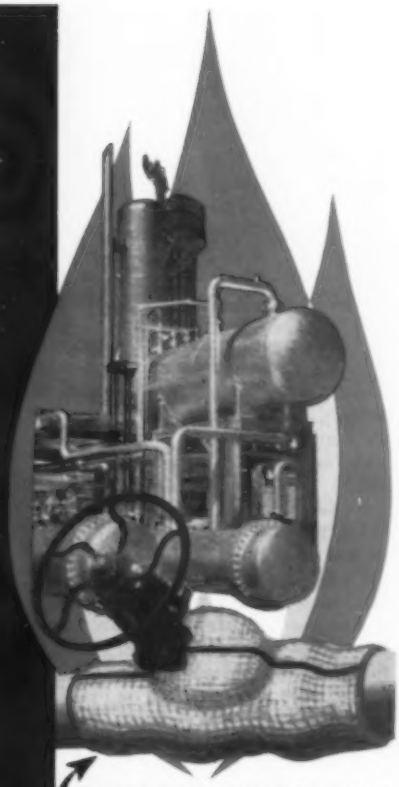

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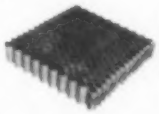

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tation. It is the basic responsibility of the application engineering department of the instrument manufacturer to furnish this factual, quantitative information and engineering assistance. In order to accomplish this, the operator must furnish all necessary factual information and data relative to the stream. In the not-too-distant future, it is quite conceivable that the entire responsibility for the choice, engineering, and installation of continuous stream analyzers will be handled by application engineering contract.

The aspect of sample handling, with regard to analyzers, must not be under-rated. Sample handling can be defined as those application engineering considerations that must be made with respect to taking a representative sample from the stream, transporting it to the analyzer, and acting upon it, either physically or chemically, while in transit to put it in a state suitable for analysis. The sampling system can introduce as many, if not more, design and engineering problems as the instruments themselves. It is sound policy to purchase the complete sample handling system along with the analyzer, to insure satisfactory installation and operation.

Current Stream Analyzers and Techniques

Infrared

The infrared process stream analyzer is one of the most important and most frequently used monitoring and control instruments. It operates on the principle of accurately measuring the amount of energy at specific wavelengths, in the infrared region, that is absorbed by the component of interest in the stream. The amount of energy absorbed at the wavelengths, selected as being specific for the desired component, is a direct function of the amount of that component present in the stream. Although generally engineered to provide data on one component, a dual analyzer version is also made to analyze, for example, CO and CO_2 in the same stream.

The instrument must be engineered to the stream, which can be a vapor, liquid, or permanent gas, at pressures up to 2000 psig. The concentration range is dependent on the component of interest, but can range from a few parts per million full scale to 100 percent full scale. The reading obtained is specific for the component the instrument is sensitized to, even though the stream may contain numerous other components. Proper sample handling to insure a clean, dust and condensate free stream of constant pressure, is an absolute necessity.

The infrared instrument is almost universal in its applications; however, the technique does have some limitations. It cannot be sensitized to detect components which do not absorb in the infrared region, such as oxygen, nitrogen, chlorine hydrogen, argon, and other monoatomic or homogeneous diatomic gases. Masking or overlapping of the specific absorption wavelengths of closely related components also limit the technique.

Gas Chromatography

The technique of process gas chromatography, though very recent, is receiving a great deal of attention in almost all industries. Due to the high specificity and accuracy of the method, combined with instrument simplicity, the applications for these instruments are virtually unlimited. It is safe to predict that within two years there should be over 2000 of these instruments on plant streams. More than 100 instruments are onstream at present.

The principle of gas chromatography is very similar to extractive distillation. A small, accurately measured stream sample is separated into its components by rapidly forcing it through a small specially packed column with an inert carrier gas. Individual components are measured by thermal conductivity upon their emergence from the column. Samples are analyzed in batchwise fashion at a rate of 5 to 15 min per analysis. The rate is a function of the complexity of the stream and the number of components of interest.

Available instruments can be engineered to handle a single component in a single stream or up to eight components in each of three streams. The instrument must be application engineered to the liquid, vapor, or gaseous stream. Its dyanamic range can vary from 0-1 percent full scale to 0-100 percent full scale.

Components in the parts per million range cannot be analyzed at the present time. Other limitations involve the boiling point of the components (this cannot exceed 300 F) and the columns' inability to separate very similar materials, such as butene-1 and isobutylene. Sample handling is of extreme importance, as is analyzer temperature control. Experience with analyzers installed on plant streams for over a year indicates an extremely low attention factor — approximately four man-hours per month.

The costs of this type of instrumentation, when figured on component basis in multiple-component analyses, is substantially below almost all other types of instruments.

Electrolytic Hygrometry

The electrolytic hygrometer is also a very new instrument. The Applied Physics Laboratories of duPont developed the technique to monitor water in Freon streams. The instrument is specific for water, and operates on the principle of absorbing all of the water from a carefully flow-controlled gas stream and continuously electrolyzing the water to oxygen and hydrogen. Current generated by this electrolysis is a direct and highly accurate measure of the water concentration of the stream.

The technique is limited, at present, to those materials which do not react with phosphorous pentoxide. Fortunately, this limitation involves only basic materials, such as amines, high olefins, aldehydes, ketones, and low molecular weight alcohols. The upper range of the instrument is limited to 1000 ppm. Accuracy of measurement depends on the range. In general, the accuracy can be stated to be ± 5 percent full scale.

Ultraviolet

This instrument operates on the same radiant energy absorption principle as the infrared, but is sensitized for the ultraviolet region of the spectrum. The major use of this instrument has been in the measurement of butadiene in fractionating columns. This application, however, is being supplanted by gas chromatography techniques. The fact that this technique is not being used to its fullest extent is most likely due to limitations in the equipment presently available. No doubt, future developments will change this situation, particularly in applications involving liquid streams.

Flow Colorimetry

Process flow colorimetry has rapidly advanced from the few "home built" instruments used in specific industries five or six years ago. Today, this technique is used in monitoring and controlling a multitude of operations in many fields wherein the measurement of color or turbidity is of critical importance.

Basically, the instrument operates on the same principles as the infrared or ultraviolet instruments. The measurement made is the amount of light of a specific wavelength that is absorbed by the component of interest, or scattered, in the case or turbidity. The magnitude of the light absorption is a function of the component concentration. Where the turbidity and color of the stream are both varying, it is possible, by means of a ratio recording colorimeter, to cancel the effect of turbidity and measure color accurately. This is true even if the stream is extremely "noisy"; that is, contains bubbles, particulate matter, and like interferences. With this same instrument, it is possible to measure continuously at two

wavelengths and record the ratio of the two measurements.

The instrument must be application engineered for each individual problem. Filter selection, cell length, and other parameters must be fixed to allow the data obtained from the instrument to be correlated to concentration or to other methods of color measurement, such as Saybolt, Union, NPA, or Hazen color numbers.

This technique has found wide application where a product color that exceeds specifications allows a premium price or better acceptance. Explosion-proof colorimeters are being used to monitor the color of gasolines, lube oils, and other fuels. Applications for the standard units include monitoring the wax color in the contact clay decolorization operation, bleaching of vegetable oils, and measurement of turbidity in boiler water.

Another wide area of application for this instrument is through the medium of color development. Here, special reagents which react with the component of interest can be added to a small side stream allowing its concentration to be measured. This method is very attractive in monitoring materials in the parts per million range.

pH

The measurement of pH is one of the oldest true stream analysis methods used. Generally, this form of instrumentation is thought of as only measuring the acidity or alkalinity of a stream. Actually, the method has far greater potential if used with accessory equipment. As an example, a pH instrument used in conjunction with a scrubbing system allows the reliable measurement of specific atmospheric pollutants. If a specially sensitized electrode system is used, a very rapid measurement of chloride ion is possible over the range of 0.1 to 10,000 ppm. Other types of electrode systems are feasible.

pH control systems require careful engineering, due to the nonlinear nature of the pH-concentration curve. Equipment now available allows pH to be measured in streams at pressures up to 100 psig and temperatures to 212 F. Accessories to overcome problems, such as electrode coating and insertion of electrodes directly in tanks or pipelines, have been responsible for the extremely wide acceptance of pH instrumentation in every field.

Basic limitations of the technique at this time are pressures over 100 psig, temperatures over 212 F, high concentration of acids and bases, and necessity of the presence of water to allow ionization. Almost invariably, solutions to problems having these limitations can be devised.

Mass Spectroscopy

A mass spectrometer may be described as an instrument for sorting and measuring charged particles according to their mass numbers. In terms of actual operation, a small quantity of sample, held at high vacuum, is ionized by an electron beam. The resultant ions are accelerated and separated by controlled magnetic and electrostatic fields. When these ions are focused on a target, the current generated as they are discharged becomes a direct measure of the concentration of the mass range in focus.

Due to its high sensitivity to trace components, as well as its ability to analyze for many different elements and compounds, the mass spectrometer shows promise in the role of a process monitoring device where other less complicated techniques are unsuitable.

The major limitations of the instrument as a process device are due to the maintenance of the high vacuum system and the rather involved electronics. Sample handling and sample systems can also create special problems. A small number of mass instruments are successfully monitoring streams at the present time. In general, it may be stated that although this technique may be suitable where all others fail, critical evaluation of the application should be made to justify the maintenance expense involved.

Refractive Index and Dielectric Constant

These two techniques are quite similar in their application; however, the two instruments are completely different from a design point of view.

The continuous refractometer operates on the principle of accurately measuring the degree of deflection of a beam of light as it passes through a transparent sample held at constant temperature. The magnitude of the angle of deflection is proportional to the concentration of one component in a binary system.

The limitations of this technique are obvious. The sample must be liquid, and must be clear and transparent. Theoretically, the technique is applicable only to a binary mixture; however, this limitation can frequently be overcome by handling a ternary or quaternary system as a pseudo binary.

Usually, these analyzers are calibrated empirically, since the correlation of refractive index with composition is not linear. An example of an important application of the continuous refractometer is in the measurement of the degree of polymerization of a liquid polyethylene stream. This measurement is virtually impossible by any other means.

The dielectric constant instrument operates on the principle of measuring the electrical capacitance of a stream, either liquid or gaseous, flowing between two fast condenser plates. The limitations of this technique are virtually the same as with the continuous refractometer, except that the streams do not have to be perfectly transparent.

It is quite possible, with this technique, to achieve a remarkable degree of sensitivity; for instance, controlling the overhead of a fractionating column separating a mixture of ortho and para chlorotoluene. In this application the purity of the overhead product can be controlled to 0.01 percent. Other applications include monitoring toluene concentrations in hydroformer distillates measuring total aromatics in a sulfur dioxide extraction unit, monitoring bs&w of crude oils, and monitoring parts per million water in liquid hydrocarbon streams.

Oxygen Measurements

There are two basic methods of instrumentation for the continuous determination of oxygen. The first, and perhaps most reliable, is based on the magnetic principle. This type depends on the displacement of a glass dumbbell, which is present in the magnetic field, by oxygen, which is attracted very strongly to the field. The degree of displacement of the body is a direct function of the oxygen concentration. These instruments are very reliable and highly accurate.

Sample handling is extremely important in the proper application of these types of instruments to process streams. In general, they are useful over the ranges of a minimum of 0-5 percent to 0-100 percent oxygen, with a full scale accuracy of ± 1 percent.

The second method for the determination of oxygen depends on the polarization of an electrode. In these types of instruments, the sample to be analyzed passes through a hollow carbon electrode by diffusion. The hydrogen that is normally evolved polarizes the cell. Any oxygen contained in the sample combines with the active hydrogen and causes depolarization.

There are many types of these cells available; however, very great care must be used in applying them to plant streams, since impurities and other interference effects can greatly affect the accuracy of the readings. In general, this method is utilized in the determination of low concentrations of oxygen.

Another type of electrode has recently been introduced that overcomes, to a great degree, these limitations. This is the Clark-type electrode wherein a plastic film that is permeable to oxygen prevents the interferring elements from coming in contact with the active electrode. ★ ★ ★

Automation 57

What is ahead for...

DIGITAL COMPUTERS

In Refinery Process Control

Closed-loop digital computer control may be just around the corner. Here is how they can and might be applied

C. G. Laspe
Technical Staff
Ramo-Wooldridge Corporation

FOR nearly a decade engineers have been heralding the advent of the automatic factory. As early as 1948[1] some of the basic concepts were being formulated. In the intervening period, numerous papers have been written[2, 3, 4] many of which have contributed to a better understanding of some of the problems involved in the complete automation of a petroleum or chemical processing plant. While most of the foregoing articles are informative and interesting, they deal mostly with the broader aspects of the problem. In any event, they are all in accord with the use of a computer as the central control element. More recently, Phister and Grabbe,[19] have described the use of systems-engineering techniques in applying digital computer-control to a chemical conversion process. Stout and Laspe[11] have described some of the tasks which may be assigned to the digital-controller.

Many questions are being asked by process people today. No doubt many of you have heard the following:

1. Are we ready for computer control?
2. How may digital control systems be justified?
3. What is the current status of the computer control art?
4. Specifically how may a digital computer controller be used to control a particular process? and lastly,
5. What does the future hold for this new technology?

Here are some answers to these questions, keeping in mind the aspects of the problem which are peculiar to the petroleum refining industry.

Are We Ready for Computer Control?

There seem to be three major areas of concern exhibited by process people when confronted with the above question. Specifically these are:

1. The seeming lack of necessary analytical instruments,
2. The apparent lack of process knowledge, and
3. The question of reliability.

Let us briefly examine each of the above items to determine how great an obstacle each one might impose upon the use of computer control.

Analytical instruments. Admittedly it would be desirable to measure directly each analytical property which is to be controlled. Today, we still find the lack of certain types of reliable continuous analyzers for the measurement of octane numbers, end boiling points, etc. This lack of instrumentation does not mean these values cannot be controlled. In many instances, an inferential measurement will suffice. For example, dielectric constant can be correlated with the octane number of catalytic reformates[15] and for control purposes may be used in lieu of the latter analytical property. In addition, refractive index measurement is a classical method of controlling the composition of binary mixtures.

On the positive side of the picture, rapid strides are being made in the development of many different types of continuous process analyzers. Infrared, ultraviolet, and X-ray spectrometers; the mass spectrometer, and gas chromatographs are filling the need for composition analyzers. Excellent instruments are available for the measurement of density, refractive index, viscosity, dielectric constant, pH, and

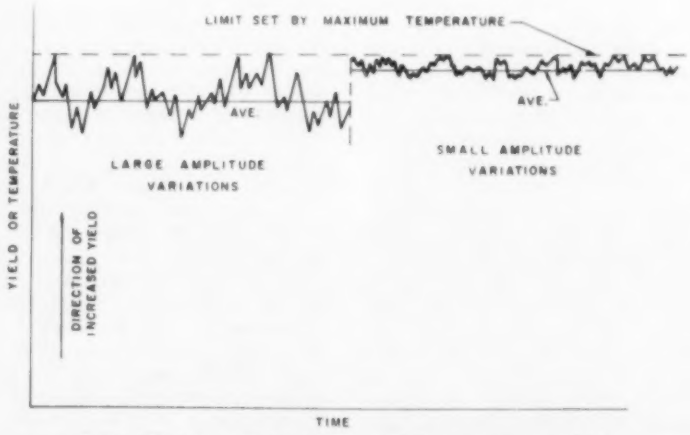
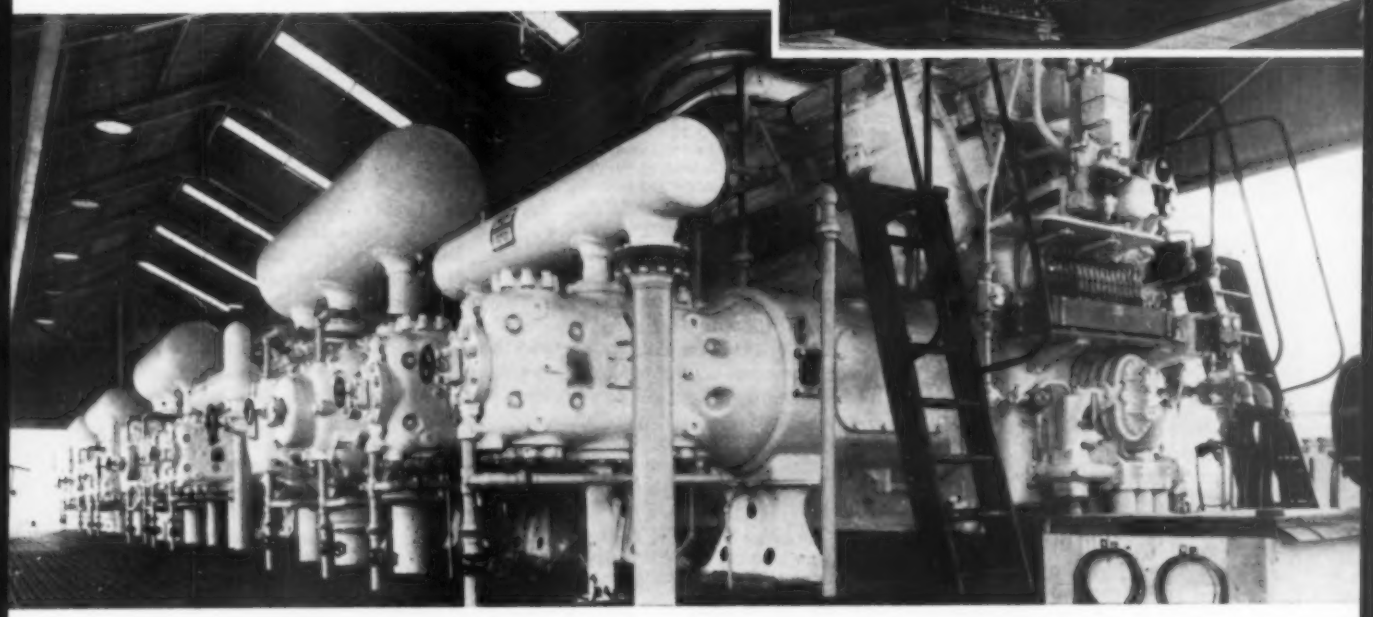


FIG. 1. Effect of amplitude of process variations upon average yield.

In the Fairbanks station of The Liquigas Company, a subsidiary of The Murmanill Corporation . . . three 8-cylinder Cooper-Bessemer GMVA's rated 1100 hp at 300 rpm and one 4-cylinder GMVA rated 540 hp at 300 rpm.

Noted for "pulling ability", Cooper-Bessemer engine-driven compressors at Fairbanks deliver long-life service with minimum maintenance.



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conductivity, to name a few. Application of these instruments is well documented.[4, 5]

The point is this: While it may still be impossible to measure continuously a particular variable, in many instances it is possible to infer the value of this missing variable by means of a correlation with one or more of the other variables which can be measured. Further, other possible control schemes can be formulated which may not require the use of the "unmeasurable" variable.

Process knowledge. Just how valid is the argument that "enough is not known about the process" to apply computer control? Let us pose this question: How many processes in operation today were completely understood at the time they were started up? Even after many years, some of the vagaries of a particular process will defy understanding and yet that process may be quite operable and profitable. It is a well-known fact that after 15 years, there is much yet to learn about catalytic cracking.

Notwithstanding, these plants have been operated successfully and, through the years, enough know-how has been accumulated to formulate at least an approximate mathematical model of the process. With the digital computer control system, many of its benefits may be enjoyed with only an approximate knowledge of the mathematical process model. Then as further data will refine the model, such refinements can be incorporated in the computer program. The basic control scheme itself, in most instances, will not require changing.

Reliability of digital control systems has received a considerable amount of attention during the past couple of years. Some people, because of unfortunate experiences, are prone to judge all electronic equipment by the performance of their table model radio or television set. Such comparisons are not valid since these latter items are mass produced for home consumption where reliability is not the major concern.

On the other hand, many refiners are well aware of the excellent performance given by the industrial-type electronic potentiometers in such critical services as furnace, distillation column, and reactor control. With the use of the solid state devices, such as the transistor and crystal diode, the reliability of electronic equipment is far exceeding that of the venerable electronic potentiometers. The useful life of some solid state devices has been estimated to be in excess of 800,000 hours. This, of course, is only one phase of the reliability question.

The Author

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A second aspect of the question is "What happens when a computer component fails?" Perhaps the simplest way out of this problem is to provide for fail-safe operation in essentially the same manner as is done with conventional pneumatic control equipment. As envisioned at the present time, a digital computer will not be connected directly to valves, dampers, or any other final control element. The computer will merely provide the set-point signal upon which the conventional controller takes action. With this type of arrangement, two possible solutions are afforded in case of computer failure. The set point can remain in its last position before failure or it can be arranged to assume a fixed but safe value.

As a further precaution and to provide the utmost in system reliability, the digital control computer can be made to check itself periodically by means of a test problem which would be incorporated as part of the program.

To answer the initial question, it must be concluded that digital techniques can be successfully applied to many existing processes.

Payout of Digital Control Systems

High Yields. It will be readily admitted by most refiners that many of their plants are not continuously operating at peak efficiency. If, for example, the yield of a particular product is dependent upon a variable which is close to a maximum limit, it is human nature to operate with this variable set somewhat below this limit, in order to accommodate the normal plant "swings." Any control system which can reduce the amplitude of these instantaneous variations may legitimately claim credit for the increased earnings resulting from the higher yield attainable by operating closer to that maximum limit. This point is clearly brought out in Fig. 1 in which a typical operating record is shown as a function of time. Note that the decreased amplitude of variation makes possible a much higher average yield of the product.

Product quality is another area in which substantially increased earnings are possible by the closer control attainable through use of digital techniques. Most products have at least one major specification which is limiting the process in one way or another. Here again the amplitude of the process variations play an important part. Fig. 2 is a typical quality control record of a plant showing the effect of both large and small quality variations. In order to insure that any one batch or shipment of material will meet specifications, it is evident that the average quality of the product must be much better than the minimum specified

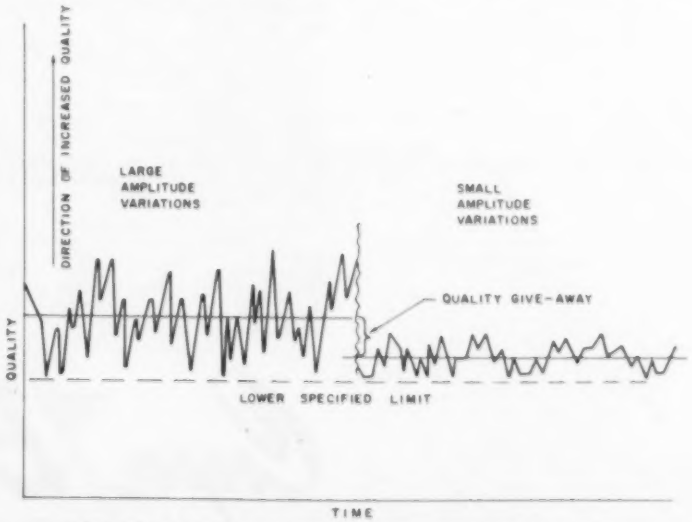


FIG. 2. Effect of amplitude of process variations upon average quality.

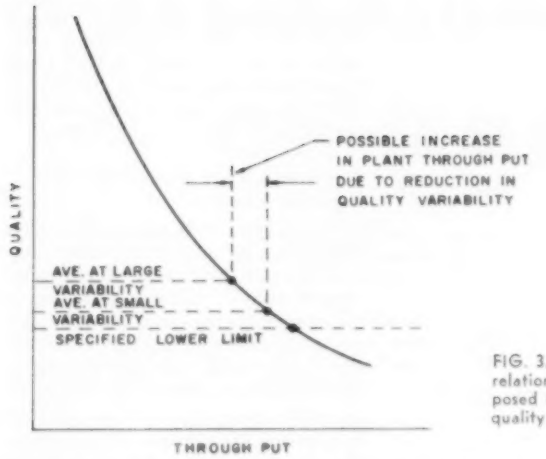


FIG. 3. Typical quality-throughput relation, showing limitation imposed on maximum throughput by quality variability.

quality. This, of course, is quality give-away. The greater the variation, the greater will be the give-away.

The choice of how to take advantage of better quality control is a matter for individual evaluation. At least three avenues, however, are open. First, it is possible to lower operating costs, especially if quality attainment is expensive. This may be the case in gasoline blending where tetraethyl lead costs are a major factor. Second, it is possible to strengthen the competitive sales position by exploiting the superior quality of the product produced by the improved control system.

The third benefit however, may be the most profitable. Most processes have a general functional relationship between quality and throughput as is exhibited in Fig. 3. As is generally true of all equilibrium processes in which yield and/or quality are affected by holding time, the quality suffers as the feed is increased. Note that smaller variabilities definitely allow greater plant throughputs to be attained without any sacrifice in quality. If additional feedstock is available, greatest monetary return will, in all probability, result from maximizing the throughput.

Attaining the optimum. So far, all of the discussion has been centered around processes that are limited by operational variables or by product specifications. In some instances, a definite, attainable optimum may be encountered. It is evident, in these cases, even though the average plant operation may be centered around this optimum, that a considerable loss in revenue may occur due to normal plant fluctuations.

Fig. 4 illustrates how this may happen. Plotted in this figure is a typical operating cost curve for a particular variable which shows a minimum or optimum value. On a vertical axis passing through the optimum value is plotted a time function representing the variability of plant operation. Values of this latter function, reflected off the cost curve, result in a curve representing the instantaneous operating costs. The area between this derived cost curve and the line marked minimum cost gives the total revenue that is lost for the period of time under consideration.

If the average plant operation were not centered upon the optimum point, then it is evident that there would result a further decrease in revenue. One of the main objectives of the digital control system, then, is to optimize the process and to reduce variability.

Role of data loggers. What worth can be attached to a data logging system? Most processing people are agreed that *per se*, data loggers cannot be fully justified in a great number of applications. There are, however, many direct and tangible benefits as well as many intangible ones that may be derived from the use of data handling systems. It is worthy of note that the mode of communication between the digital computer and the operator is by means of an electric typewriter. Because of this, one of the subordinate duties of the process control computer could be the function of a data logger.

In addition to the normal data handling function, the digital control computer can also provide the services of a superb and sophisticated process trouble shooter. Normal alarm conditions are handled easily. There are, however, instances in which several symptoms must be judiciously correlated in order to properly diagnose a faulty operating condition. A high level signal from a level controller may be the result of a faulty instrument. But this, coupled with a low flow rate from the vessel, may spell trouble. If the seriousness of an operating situation would warrant such a service, a trouble-shooting diagnostic function could easily be built into the computer program.

What Has Been Done to Date?

There are, to the writer's knowledge, no complete closed loop digital com-

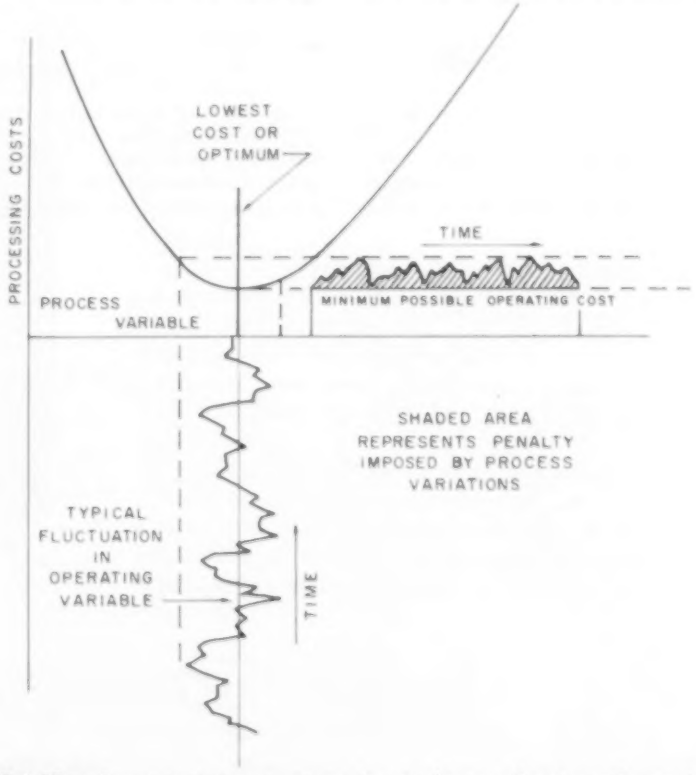


FIG. 4. Effect of process variations upon processing cost when operating at an optimum point.

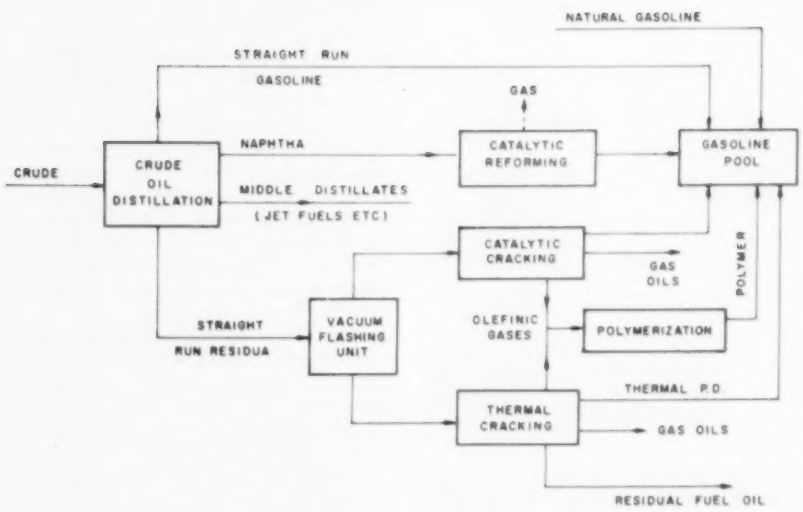


FIG. 5. Flow scheme of a typical refinery processing naphthenic base crude oils.

puter control systems other than those used in military applications. Recently, however, the results of some exploratory tests have been published. The duPont Company and Burroughs conducted an experiment to demonstrate the feasibility of digital control.[17] A series of measurements taken at the Niagara Falls plant were digitized and transmitted via telephone circuits to the Philadelphia office of Burroughs. Yield and material balance computations performed on the above measurements were relayed back to Niagara Falls for use by the plant operators. In addition, these same results were simultaneously projected on a screen in the executive offices of the duPont headquarters in Wilmington, Delaware.

Several literature references[8, 9] describe the installation of a data-logger-analog computer combination at the new Esso catalytic cracking plant at Belot, Cuba. According to the published reports, the computer will calculate, each hour, eleven operating guides useful for overall plant control. Here, again, the system will be of the open loop type.

The Case Institute of Technology has recently published a technical report[6] describing the use of an analog computer to continuously optimize the batch hydrogenation of cottonseed oil to produce oleomargarine.

Perhaps the only closed-loop large-scale computer control system in use today is the "Early-Bird"[7] analog controller which is used to automatically allocate the load to the various electrical generating stations in the Southern Company's power pool.

The above installations, while they may not be striking nor melodramatic, certainly indicate the goal toward which the control technology is aiming. It is an old adage that we must crawl before we can leap. Certainly, the computer control system has demonstrated its ability to crawl.

Application of Computer to Process Control

As a timely example of a process which may be suitable for digital computer control, perhaps the catalytic reformer is one of the more intriguing.

Let us briefly consider the hypothetical refinery as diagrammed in Fig. 5. As will be noted, the flow scheme is quite typical of a refinery processing an asphaltic or naphthenic base crude oil to produce the greatest yield of gasoline. As is common with many refineries of this type, it will be assumed that the gasoline pool, excluding catalytic reformate, even at the maximum allowable usage of TEL (tetraethyl lead), will fall somewhat short of the octane number requirement. This situation makes it mandatory of course, to operate the reformer at a reaction severity which will balance the deficit in the pool octane number.

A further interesting possibility arises. At the higher TEL levels, more severe reforming, even at the expense of some lost production, may be more profitable than the use of additional TEL. An optimum may, therefore, exist in the choice of reforming severity.

Fig. 6 is a correlation of operating variables for the hypothetical catalytic reforming plant. The typical yield octane number relationship has been assumed in constructing this diagram. Improvement in feedstock quality results in a proportionate improvement in the reformate quality. Parametric

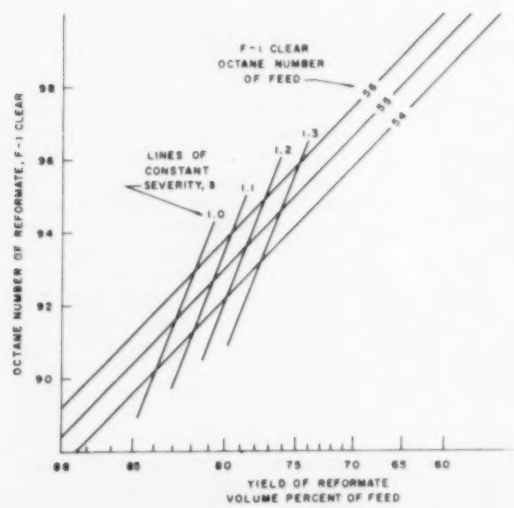

F-1 CLEAR OCTANE NUMBER OF FEED
LINES OF CONSTANT SEVERITY, B
OCTANE NUMBER OF REFORMATE, F-1 CLEAR
YIELD OF REFORMATE VOLUME PERCENT OF FEED

FIG. 6. Typical yield-octane relationship for catalytic reforming operation.

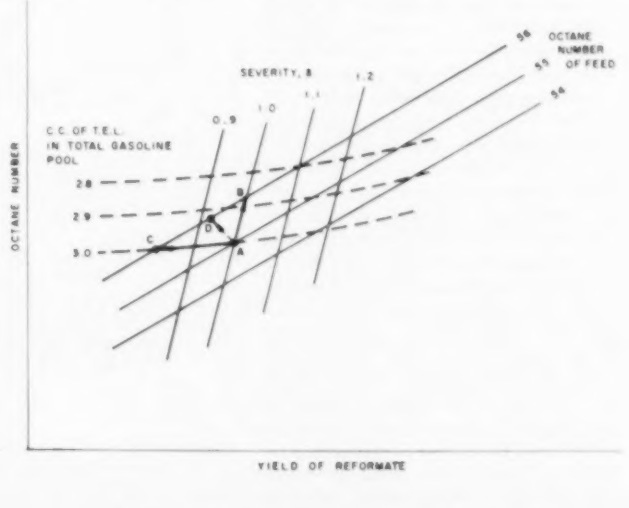


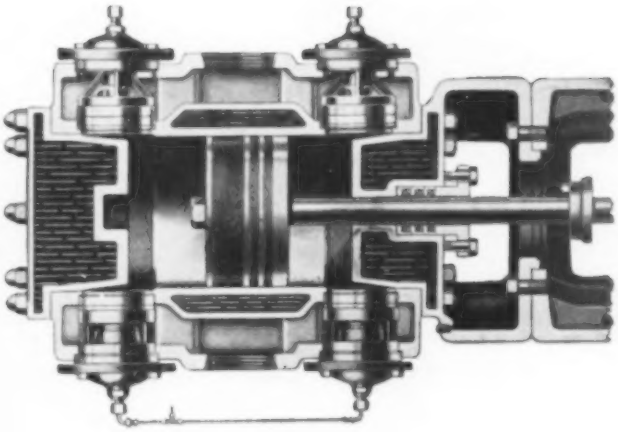
FIG. 7. Effect of reforming severity upon TEL requirements.

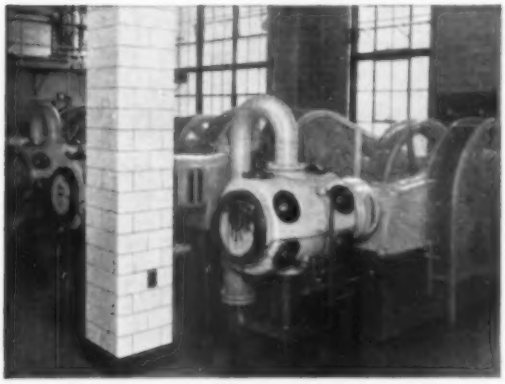
A dependable supply of

oil-free air or gas

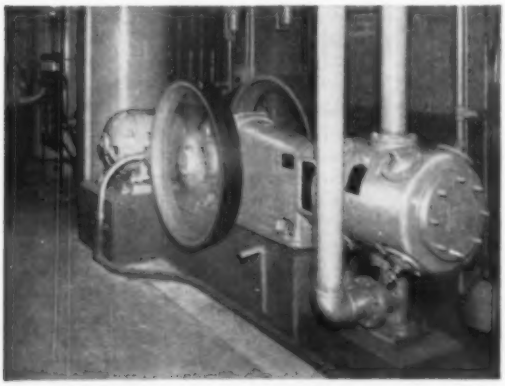
Graphitic-carbon wearing rings and pressure rings prevent metallic contact between the piston and cylinder bore—no oil is used anywhere in the compression cylinder or on the piston rod.

NL Channel Valves are designed specifically for non-lubricated service. Carbon guides protect channel ends and special Teflon strips protect channel interiors and spring ends from metal-to-metal rubbing and wear.





Installed in a large brewery in 1933, this Ingersoll-Rand ES-NL compressor was the first unit ever built with non-lubricated cylinders. It is still in daily service, providing the clean, oil-free compressed air which is vital to product purity. Three other ES-NL compressors, installed since then, are shown in the background.



One of four ES compressors with NL cylinders, supplying oil-free air in the manufacture of super-precision instruments and aircraft ball bearings.

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ES-NL

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In process and manufacturing plants all over the world, the problem of oil contamination in compressed air and gases has been successfully solved by the application of Ingersoll-Rand ES-NL compressors.

The unique NL cylinder design provides compression without oil lubrication—through the use of graphitic-carbon wearing and pressure rings. The ability of these compressors to deliver clean, oil-free air and gas, in continuous, heavy-duty service, has been thoroughly proved in every field of application.

If you have an application where oil-lubricated compressor cylinders cannot be used, ask your Ingersoll-Rand representative about the ES-NL compressor, sizes 5 to 150 horsepower—other Ingersoll-Rand NL compressors to 1000 hp.

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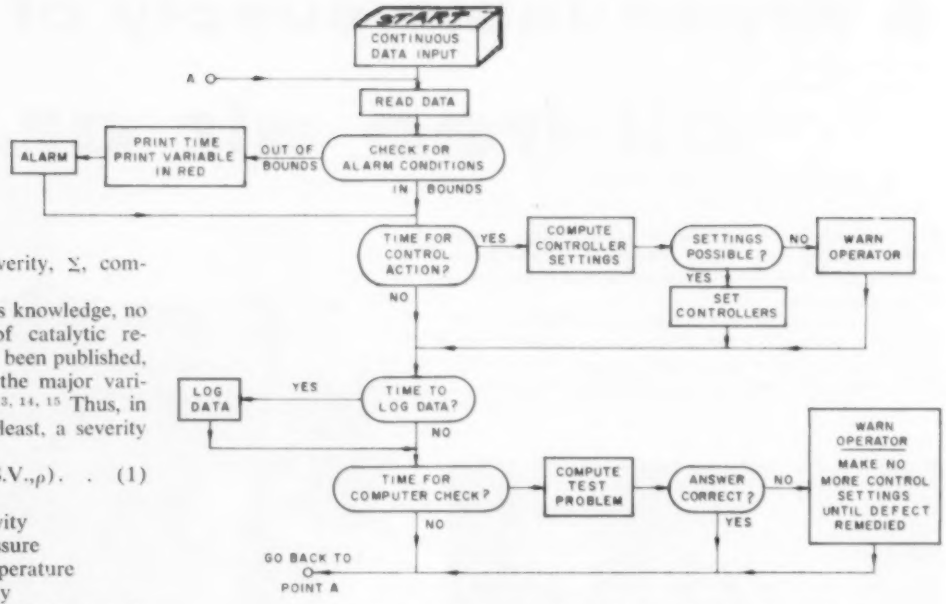

FIG. 8. Possible general program to be used by process control computer.

lines of reforming severity, Σ, complete the plot.

While, to the writer's knowledge, no general correlations of catalytic reforming variables have been published, the general effects of the major variables are well known.[13, 14, 15] Thus, in a functional form, at least, a severity factor can be written:

$$\Sigma = f(k, P, T, S.V., \rho) \quad . \quad . \quad (1)$$

where:

k = catalyst activity
P = reaction pressure
T = reaction temperature
S.V. = space velocity
ρ = hydrogen-to-feed recycle ratio

In Fig. 7, a section of Fig. 6 is reproduced over which a new set of parametric curves representing the gasoline pool requirements, has been plotted. These latter curves are defined by the following equation:

$$\frac{Q_p + Q_r}{Q_p + Q_r} = N_s \quad . \quad . \quad (2)$$

where:

Q_p = quantity of gasoline in pool excluding reformate
Q_r = quantity of reformate
N_p = octane number of pool excluding reformate
N_r = octane number of reformate
N_s = octane specification

The intersection of the parametric curves with the applicable yield-octane line represents a possible operating position. Since the position is a function of TEL level, its optimum location can be determined only by an economic computer involving the gasoline pool and the catalytic reforming plant. Since this computation is somewhat involved and lengthy, a very fruitful area for the application of a digital process control computer now arises. This situation is especially true in processing plants in which little intermediate storage is available, which may result in frequent changes in reformer feedstock quality and quantity. Just as frequently as these changes occur, the reforming severity should be altered to conform with the maximum economic return.

How the computer fits in. The role played by the computer will become more apparent after considering a typical sequence of events. In Fig. 7, let us assume that the reformer is operating at a point "A." Suddenly the octane number of the feed is increased by one unit. (Such a change might occur when switching feed tanks.) At constant severity, point "B," a higher reformate octane number is produced giving rise to the possibility of reducing the overall TEL consumption. On the other hand, if the TEL level is to remain constant, the reaction severity could be decreased to point "C" with a resultant increase in yield. Somewhere between these two alternatives may lie a maximum profit position.

The optimum point can be rapidly ascertained by the computer, by solving the following set of equations. Functional notation is used since the exact form will have to be determined for each specific application. These equations are sometimes referred to as the *mathematical model* of the process.

$$\frac{[N_p + f_1(L)_p]Q_p + [N_r + f_2(L)_r]Q_r}{Q_p + Q_r} = N_s \quad . \quad . \quad . \quad (3)$$

$$N_r = f_3(\sigma, A, N_f) \quad . \quad . \quad . \quad (4)$$

$$Y_r = f_4(\sigma, A, N_f) \quad . \quad . \quad . \quad (5)$$

$$Q_r = Q_f Y_r \quad . \quad . \quad . \quad . \quad . \quad (6)$$

$$D = \overbrace{Q_r V_r + Q_g V_g}^{\text{Value of Products}} - \overbrace{Q_f V_f}^{\text{Value of Feed}}$$

$$\overbrace{-(Q_r + Q_p) V_l}^{\text{Lead Debit}} - \overbrace{Q_f C_p}^{\text{Proportional Operating costs}} - \overbrace{C_f}^{\text{Fixed Cost}} \quad (7)$$

Definitions of the above symbols are given in Table 1.

As a result of the above computation, a specific reaction severity and TEL level is obtained. To determine the optimum position, of course, Equation 7 must be differentiated and set equal to zero. It should be pointed out that Equation 7 is more complex than meets the eye, due to the fact that the proportional operating cost, C_p, is a function of reaction severity which includes the effect of fuel pumping, and compressing costs.

Data "read-in" to computer. It should be emphasized that those quantities which are involved in the direct control of the plant will be continuously "read-in" to the computer through appropriate transducing and input equipment. These quantities would most certainly include the octane number of the feed and reformate, the feed rate, effective reactor temperatures and pressures, catalyst age, and the hydrogen recycle rate. Other quantities which do not exhibit as great a time variation would have to be "read-in" less frequently. The octane number and quantity of the gasoline pool probably need be determined only once every few days or once a day at the most. This information could be manually inserted into the computer memory via an electric typewriter or punched tape. Cost data which changes infrequently could be handled in a like manner.

As yet, there is no continuous octane number analyzer commercially available. However, a recent article[18] indicates that the dielectric constant of catalytically reformed naphtha correlates very well with its octane number.

3 FROM 1

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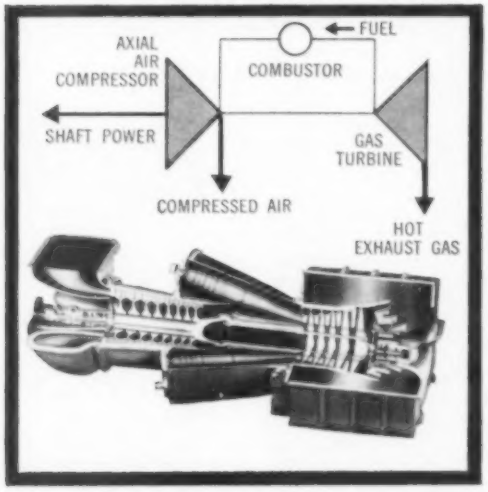

In addition, smaller line heaters and less fuel will be used because *all* the *Btu's* put into the gas turbine are exhausted to the heaters and process, with the exception of minor radiation and bearing losses.

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Shaft power.....up to 22,500 hp
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The article indicates that the correlation is sufficiently precise for octane number control. As is well-known, instruments for the measurement of dielectric constant are becoming commonplace.

Computer program. A detailed flow chart outlining the exact sequence of events in the computer program is beyond the scope of this paper. The exact form, of course, will depend upon the character of the functional Equations 3 to 7, which represent the mathematical model of the process. One possible general computer program, however, is shown in Fig. 8. Note that the computer provides alarm and data-logging functions in addition to its primary role of process control.

The decision block, entitled *Time for Control Action?* is inserted in the program in order to compensate for various process dynamics. Using the Z-transform methods of sampled data systems, it is possible to specify a data sampling interval which will result in a stable control system. Also the use of certain analytical instruments, such as the vapor phase chromatographs, which operate on a semi-continuous basis, require that such a decision be made.

After making the control computations, the computer is faced with another decision — *Are the Control Settings Possible?* If any of the variables must be set outside of prescribed limits, no action is taken and the operator warned. One specific instance arises when it is impossible to make the required quality and quantity of reformate, even at the maximum severity. In this case the computer could indicate that it was time to regenerate or to re-work the catalyst, depending upon the type of catalytic reforming plant.

A check problem is normally incorporated into the program in order to detect any malfunctioning of the computer. If an error is detected, the test problem would be repeated two or three times to check the consistency of the error. If the error persists, the computer would make no further control adjustments until the defect was remedied. During this correction period the plant would be controlled in the present conventional manner.

The above discussion, brief as it is, illustrates the type of engineering and systems analysis that must be carried out in order to provide the utmost in benefits from a digital process control installation.

What Does the Future Hold?

Any discussion on such a rapidly expanding technology as that of digital control systems would be incomplete without at least a light treatment of the subject "Where do we go from here?"

It is well-known that the improved control afforded by modern conventional instrumentation has resulted in a considerable savings in initial plant investment through the use of optimum-sized reaction vessels and the minimization of intermediate product storage requirements. The ultimate, however, has not yet been reached. A better knowledge of process characteristics, coupled with tighter control, will allow even greater savings to be effected.

Then one frequently reads of the dream of computer control engineers—a process that cannot be controlled without the use of a digital computer. Of course, no such process exists today. But with process technology advancing as rapidly as it is, who knows, such a process may be here tomorrow. Getting a little more down-to-earth, there are many processes which are marginal and only await a small technological breakthrough before they become economically feasible. Certainly the processes of coal hydrogenation and shale oil recovery lie in this province. Perhaps digital control techniques will provide the necessary profit margin to allow these processes to take their place along with the conventional petroleum refining methods and thereby increase the availability of our energy fuels supply.

It will be some time yet, before conventional control equipment, as we know it today, will be displaced by incorporation of these functions in the process control computer. There are some applications, such as simple back pressure regulators, where, no doubt, such a displacement will never occur. When the reliability of these digital machines has been proven, then we shall see more and more of the regulatory control functions relegated to the computer. This makes sense, since the conventional controllers represent a considerable investment and provide an unnecessary duplication of the capabilities already existent in the digital computer. Eventually, we should look for a decreased investment in control equipment, a decreased complexity of the control system, and finally a reduction in the size of the control room.

The ultimate, of course, will be a refinery in which a master computer will direct the operations of a series of process control computers. The beginnings of such a scheme may be seen today. Most of the major refiners and many of the smaller ones completely schedule their operations, and control gasoline blending, and stock movements by means of large scale digital data processing machines. The final step, of course, only awaits the wide scale use of process control computers.

TABLE I. Nomenclature.

N_p = Unleaded octane number of the gasoline pool with catalytic reformate excluded.
N_r = Unleaded octane number of the reformate.
L = Quantity of TEL used in total pool of motor gasoline.
$f_1(L)_p$ = Lead susceptibility of the gasoline pool (excluding reformate).
$f_2(L)_r$ = Lead susceptibility of the reformate.
Q_p = Quantity of gasoline pool (excluding reformate).
Q_r = Quantity to reformate.
Q_f = Quantity of feed to reformer.
Q_g = Quantity of gas from reformer.
Σ = Reforming severity factor.
A = Catalyst activity (age).
$Y_r = \text{Yield of reformate} = \frac{Q_r}{Q_f}$
D = Dollar profit from reforming operations.
V_r = Unit value of the reformate.
V_g = Unit value of gas from reforming.
V_f = Unit value of feed to reformer.
V_l = Unit value of lead (TEL).
C_f = Fixed operating costs.
C_r = Proportional operating expenses.

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★ ★ ★

DU PONT *Petroleum Chemicals* NEWS

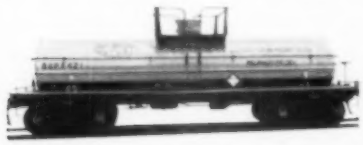
Number 79 in a Series of Bulletins for the Petroleum Industry

SEPTEMBER 1957

New survey reveals hidden buying motivations of service station customers

Refiners realize substantial savings by purchasing additives in quantity

If you are now buying your additives in drums, you can *save well over a thousand dollars each time you order* a DuPont additive by the tank car.



With DuPont Fuel Oil Additive No. 2, for example, a Mid-Continent refiner can save 8.4% on a carload by simply taking delivery in a 4000-gallon tank car instead of an equal quantity in partial car drum shipments. With DuPont Antioxidant No. 22, the savings range as high as 8.9%.

These figures are, of course, based on freight rates between specific points, and the savings vary according to the shipping distances.

How much can YOU save?

To answer that question for you, one of our representatives will be glad to call at your refinery and study applicable freight rates and inventory patterns. He will then determine the most convenient handling method for you, and figure the exact saving you can make.

Still another in a series of Du Pont-sponsored surveys has recently been completed by National Analysts, Inc. The findings will soon be available in booklet form.

The objective of the survey was to determine what emotional reactions influence motorists to choose a service station, a brand of gasoline, or a TBA product.

THE NEW DUPONT MOTIVATION SURVEY REPORT has been packaged as a convenient flannelboard presentation. Roberts W. Brokaw, of Petroleum Chemicals Sales Promotion, demonstrates here how the results can be presented at meetings in easy-to-understand form.

Psychological needs

The psychologists in conducting the study determined that there are four basic needs which can be fulfilled through purchase of service station products and services:

1. **Play**—use of car for recreation

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OVER

CONTINUED

New Survey

2. **Aggression**—desire for speed and fast acceleration
3. **Conservance**—need to preserve car as an investment
4. **Infavoidance**—the desire to avoid the *appearance* of inferiority

Specific products

Gasoline sales, as you might suspect, are most influenced by the play and aggression needs. This finding indicates that gasoline advertising should appeal to motorists' desire for recreation and powerful car performance.

It was found that motor oil and grease satisfy the conservance need. The promotion of these products should be directed accordingly. Body polish, which might be thought to satisfy the conservance need, actually gratifies more often the need for infavoidance. So do white sidewall tires.

Anxiety influences

Two of the areas explored were anxieties about product quality and service.

Apparently women drivers are more concerned than men about tire quality and repair. This may be because a flat tire is a greater inconvenience to women.

Women appear to have also a more generalized anxiety over automotive products they buy. This is possibly due to their having, in general, less mechanical knowledge than men.

Perceptions of service stations

Motivational needs lead to motorists' perception of different service stations as places to do business. Perception is influenced also by the opinions of others, including families, and by advertising and promotion of the dealer or the company he represents.

A summary of the findings of the survey are being published in book form for easy reference.

AUTOMOTIVE SERVICE OFFERED

I. T. (TED) ROSENLUND (right) says that actual under-the-hood technical service work on refiners' automotive problems is his greatest source of new ideas. And many of his ideas have resulted in unique demonstration equipment which enables refiners and marketers to prove their product quality to dealers and customers.

He is responsible for the design and construction of practical demonstration equipment for the Petroleum Chemicals Division. This equipment must make somewhat intangible fuel and lubricant properties come to life in the form of noise or motion. With it petroleum refiners and marketers can show their dealers and customers the quality built into their products.

Wide experience

Ted's long experience in automotive service work also enables him to assist in resolving particularly difficult problems as they arise.

Ted joined the DuPont Company in 1947 as manager of the Petroleum Chemicals Division's road test laboratory. Between 1942 and 1947, he had been fuel and lubrication engineer for the Allison Division of General Motors and a project engineer on combustion chamber design and development at the Packard Motor Car Company's jet engine division. Prior to 1942, he spent several years with a major oil company as research engineer on aircraft engine oil development.

Ted graduated from the University of Michigan with a BS degree in aeronautical engineering, majoring in engine design. He is a member of the Society of Automotive Engineers.

Expanded additives warehouse to serve Pacific Northwest area

The DuPont Petroleum Chemicals Division recently expanded its additives warehouse near Seattle.

Ideally located to serve the fast-growing refinery industry in the Pacific Northwest, it will continuously house an ample supply of all DuPont petroleum additives (except tetraethyl lead). The complete DuPont line includes Fuel Oil Additive No. 2, DuPont Metal Deactivator, dyes, antioxidants, and grease additives.

For fast deliveries

Arrangements with a local truck line plus the permanent warehouse staff will help considerably to expedite deliveries of DuPont additives to refiners.

DuPont TEL is supplied to refiners in this area from a DuPont "warehouse on wheels" at Ferndale, Washington.

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OVER

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Sohio finds...

ANALOG COMPUTERS

Ideal for Process Analysis

Found an invaluable aid in other industries, the analog computer shows considerable promise in process studies. Speed and simplicity of set up permits more detailed calculation

Warren Jackson Jr.
The Standard Oil Company (Ohio)
Cleveland, Ohio

ANALOG computers have proved to be invaluable tools in other industries and promise to become important in the process industries. In general, their use permits more detailed calculation to be performed, thus putting jobs of analysis, trouble shooting, evaluation, and design on a firmer footing. We have found the technique of simulation to be especially important in our computer applications.

The general steps of simulating consist of problem statement, problem analysis (including simplification), computer programming, and the running of experiments designed to evaluate performance under a variety of conditions. This can be done for actual or proposed equipment. Some of the answers sought can be specifying design factors, determining stability, evaluating competing systems or merely a better understanding of a system.

The analysis phase can be extremely difficult. Detailed data required by the computer must be gleaned from all possible sources—experimental data, plant records, theoretical analysis, statistical correlations, suppliers' information, and others. However, when a computer is logically programmed with this data, it can be a valuable tool for the reduction of the data to practical information.

Sohio's Process Engineering Division has had a medium size general purpose analog computer in operation for over a year. It is the kind generally referred to as an electronic analog differential analyzer. While the sum total of our experience is not large, the application of these techniques is so new to the petroleum industry that a discussion of our efforts may be useful to others.

Presented at the Regional Meeting of the Western Petroleum Refiners Association, February 7-8, 1957, Houston, Texas under the original title "Analog Computers in Process Analysis."

Technique of Simulation

The general technique of simulation, which has been most useful, consists of setting up a mathematical model of the process system or situation concerned, programming it on the computer, and performing experiments to determine such things as performance, operating conditions, design parameters, etc. Setting up of the problem can be done piecemeal so each segment of the problem can be studied and simulated separately. The final programming on the computer then connects these portions together to produce a complete model.

The model should then behave like the system in the problem within the accuracy of the analysis and the computer. In general the computer's accuracy is far greater than the problem data accuracy and so represents no problem. This technique of analog simulation permits us to work with something which seems fairly familiar. The knobs, switches, meters, and recorders on the computer are sufficiently like the controls and instruments in a process that the problem solver feels quite at home. This, in effect, gives the man a pilot model of his process or system to experiment with without the difficulty of size scaling usually associated with pilot equipment.

Some advantages in using this approach to problems are:

1. More thorough and complex calculations can be accomplished than when using desk calculators.
2. It is cheaper and safer, when applicable, than performing plant or pilot plant tests.
3. Procedure is more flexible than lab or plant tests especially when new ideas are to be evaluated which would involve the construction of apparatus.
4. The time scale of the model can be speeded up, thus allowing many more experiments in a given amount of working time.
5. Plant production is not upset by this method.
6. The problem solver obtains a

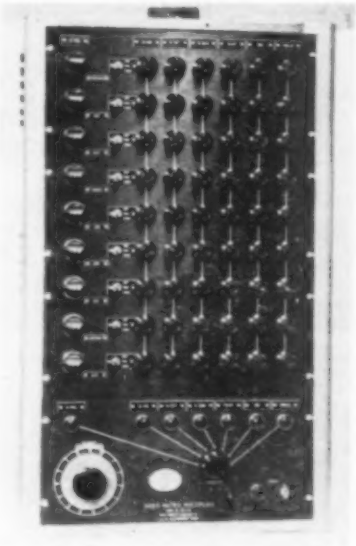

FIG. 1. Special purpose computers are smaller, cheaper and easier to use but have limited range.

better feel for his problem because he can watch or record any of the variables in the problem during the experiments. This frequently produces by-product information and promotes new ideas.

7. The problem solver is forced by the nature of the computer operation to thorough analysis of the problem.

As with most computer techniques the actual computation time for a problem is relatively small. Usually the greatest amount of time is spent in problem analysis. Programming for the computer is usually straightforward and can be done by anyone with some previous experience. Setting up the computer, and operation during experiments is done by a technician who is directed by the man with the problem. This phase of the problem solution is not at all difficult. For example, the problem to be subsequently discussed in detail took something like one man-month of analysis time by a number of technical specialists. The programming took about ½ man-day, and the problem board wiring about one man-hour. Several days were spent in checking out the simulation on the computer and in performing the experiments.

It is probable that the great amount of problem analysis time required will be reduced as we become more experienced in this work. In fact, we are looking forward to the time when these problems can be done to a large extent by what is known as direct simulation. This is the technique wherein problems are simulated through the use of preestablished computer circuits, thereby eliminating the mathematical analysis step. Using direct simulation, one would simulate a heat exchanger or process controller by merely consulting the library of standard circuits and programming in the particular properties of the device to be simulated.

FIG. 2. General purpose analog computers are built to perform wide range of mathematical functions.

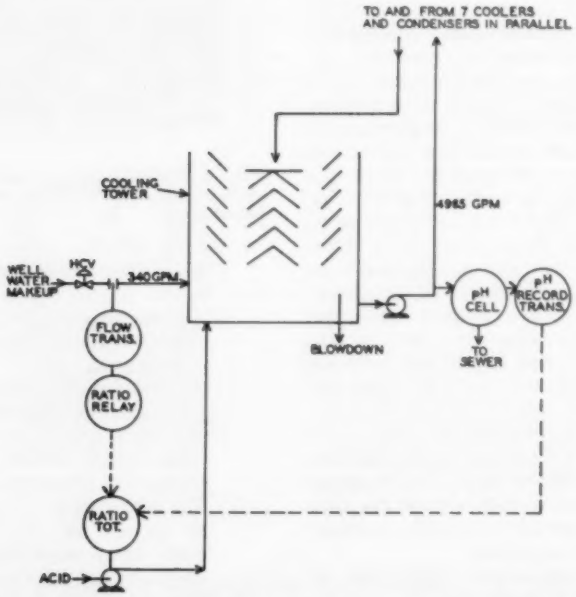

FIG. 3. Example pH control system applied to analog simulation study to obtain improved operation and determine effectiveness of system.

Computer Equipment Used

Analog computers fall into two general classes. These are the special purpose computer and the general purpose computer.

A special purpose computer is usually smaller, cheaper, and easier to use than a general purpose computer. It has gained these advantages, however, by being designed for only one particular problem, or at best a particular class of problems. An illustration of one kind of special purpose computer is shown in Fig. 1. It is a gasoline blending computer, which we call a matrix multiplier, and has been described by Karl L. Shull of Sohio's Lima refinery in a paper presented at the Regional WPRA meeting last year at Toledo, Ohio.

General purpose analog computers are usually considerably larger, nonportable, more costly, and more difficult to maintain and operate. However, they are far more flexible in what they can do. They are called general purpose primarily because they are built to perform a wide variety of fundamental mathematical operations, such as addition, subtraction, multiplication, division, integration, differentiation, etc. Our particular general purpose machine is illustrated in Fig. 2.

Areas of Application

We have used the general purpose computer as a prototype for investigating applications and designs for special purpose computers. This has allowed us to simulate a special purpose computer, such as the matrix multiplier, and to try sample problems on it before going through the steps of detailed mechanical design and construction.

We have used the general purpose computer to evaluate process control systems in a number of different circumstances. Several of these are: (1) The problem where conventional control system design is applied to an unusual process situation; (2) where

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new or unusual control systems are proposed; and (3) problems involving trouble shooting on existing control systems which do not function properly. In these situations it has proved helpful to be able to simulate the equipment involved and to run experiments on the computer.

It is possible to study reaction mechanisms on the computer through a study of reaction kinetics for various proposed reaction mechanisms. This is a trial and error procedure but is fairly rapid and convenient to do on the computer. When a proposed mechanism is found which satisfies experimental data, one has some assurance that it is the proper mechanism.

Some work has been done in the area of evaluating specific control instruments for certain common applications. The effort has been directed mainly toward comparing different makes and types of instruments in a given situation to see whether or not more expensive and complex apparatus can be justified in terms of performance. This includes such things as board-mounted versus field-mounted controllers and the usefulness of boosters.

Analog Computer Use

Our general purpose computer has been used in a number of areas. A relatively simple example, using the technique of simulation, will be described with the hope of clarifying some of the general ideas discussed earlier. This is a problem involving the pH control system for a cooling tower. The tower studied services a catalytic reforming unit. The pH control system had not been in operation very long and was performing quite erratically. In addition, one portion of the control system had not been installed. The questions essentially were:

1. Has the control system been well designed or can it be improved?
2. What is the effect of the portion of the control system not yet installed?

Concern was expressed not only for this particular cooling tower, but because a number of similar control systems were under construction or had been proposed for future installation. Fig. 3 is a simplified process drawing of the cooling circuit and pH control system.

The cooling water circuit consists essentially of seven condensers and coolers in parallel. Their flow rates and piping lengths are all different. The pH in the cooling tower basin is controlled by the addition of acid. The control system operates by having the pH of the water and the makeup water flow rate control a variable-stroke acid pump. A number of adjustments in this system were available to the operator. They are:

1. Proportional band and set point adjustments on the pH recorder controller.
2. The ratio adjustment of the ratio relay.
3. The tension adjustment on the ratio totalizer.

In addition to answering the original questions posed, we proposed to learn how to make these adjustments.

In our original approach to this problem we made a number of simplifying assumptions. The condenser network was simplified by combining those condensers which had nearly the same dynamic effects on the system. It was assumed that the continuous blowdown rate included the windage losses. Systems involving the addition of chlorine and other additives were neglected except for the fact that the effects of these materials were considered in some experiments by using their acid equivalents as an approximation. The carbon dioxide content in the basin was considered as an arbitrary parameter. Since we did not know how to predict carbon dioxide content mathematically, we provided a means for setting in any arbitrary carbon dioxide content. We then repeated a number of our experiments at various carbon

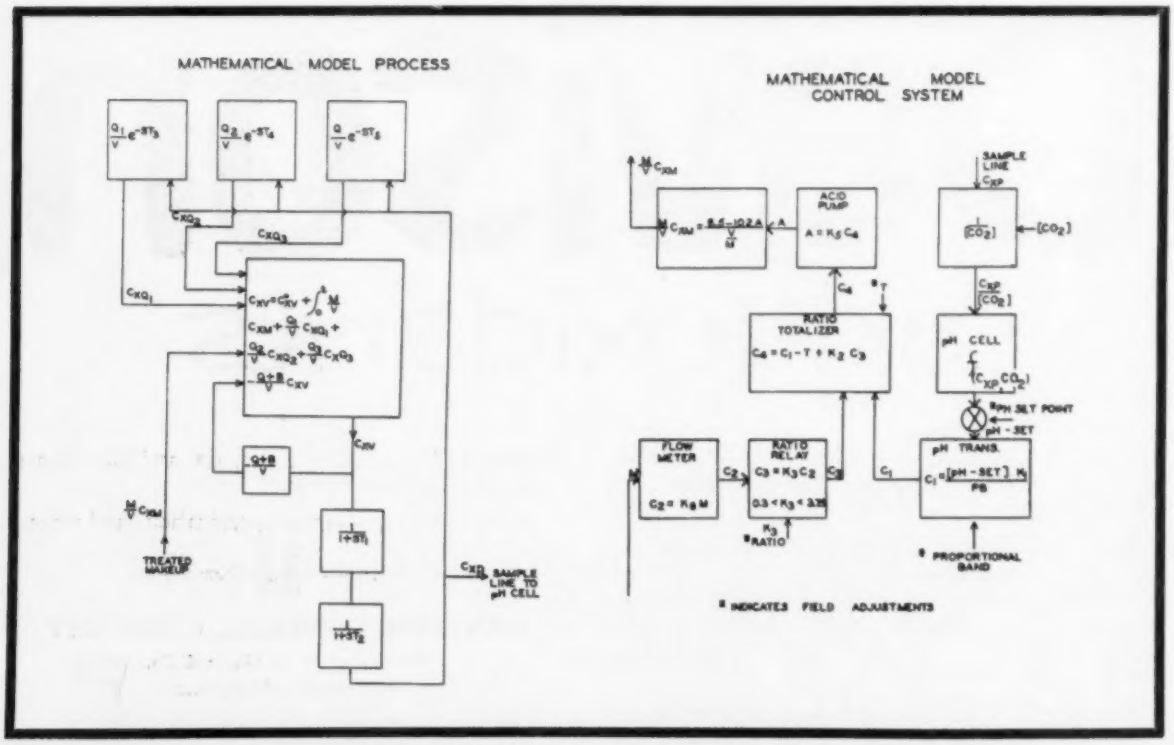

FIG. 4. Equations were derived for all components, simulating both process and control systems. Each block represents a small portion of the overall problem.

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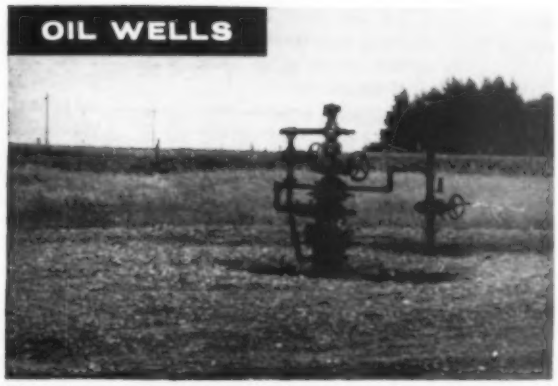

Note the excellent control of weeds and grasses around this wellhead from just one application of "Telvar."

The treated area around this tank farm has remained weed-free for an entire season.

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dioxide levels to observe the effects of this parameter. It was further assumed that all of the control instruments operated so rapidly that their dynamic effects could be neglected.

The next phase of the problem, which was by far the most difficult, consisted of deriving equations for all parts of the system under study. The results of this analysis are shown in Fig. 4. Each block represents a small portion of the problem and contains within it the equations for that portion. Condensers are represented mathematically as pure transport delays. We merely calculated the time it would take a droplet of pure water to flow from the pumps, around the circuit, and back to the basin for each condenser. Basin and pits were represented as simple exponential mixing lags wherein perfect mixing is assumed. The real difficulty in the analysis of this problem was deriving the equations which would predict pH in the tower basin as a function of the known operating conditions. This was done by calculating ion concentrations obtained through material balance calculations around the basin. The pH was then calculated from the ion concentrations by the simultaneous solution of two equations involving the hydrogen ion concentration as an implicit variable. Actually these equations were pre-solved by hand calculation and a curve obtained which related the ion concentration divided by the carbon dioxide content to pH. This curve was then programmed on the computer through the use of a diode function generator, indicated by "F" on the diagram.

These equations were checked by using them to predict the titration curve for a sample of plant well water and comparing with a laboratory titration. Instruments are represented only by arithmetic equations describing their behavior as published by the manufacturer.

The model was then operated under a variety of operating conditions, and the resulting performance observed by recording pH, acid flow rate, makeup water rate, ion concentration, and instrument air pressure versus time on a strip chart recorder.

Test Conclusions

From this experimental work we were able to draw a number of conclusions, the most important of which have since been verified by plant operation. They are:

1. The control system design is very good, being capable of excellent control with a high degree of stability. Any difficulties encountered in the field are likely to be due to equipment malfunctioning or maladjustment rather than to control system design.
2. The feed forward control loop from the makeup flow rate transmitter is very effective in reducing pH variations in the face of makeup water flow rate changes, but serves no useful purpose other than that. This is the portion of the control system which had not been installed in the plant. With sizeable makeup flow rate changes this portion of the system accounted for a pH offset reduction of from 10 to 20 times. If the makeup rate is constant, this control loop is not necessary.
3. The system is inherently stable even at the lowest proportional band adjustment attainable. With this particular equipment this adjustment was 10 percent proportional band.

The conclusions thus far stated have been confirmed by the refinery. Additional conclusions obtained include:

4. The feed back loop from the pH transmitter reduces the system response time from 2½ to 15 times, and the pH offset from 5 to 25 times for proportional band settings of 100 percent and 10 percent as compared to no control.
5. Small changes in raw water pH in the direction of a higher pH causes much less trouble than small changes in the direction of a lower pH. The same effect was observed for makeup flow rate changes without the feed forward control loop in operation.
6. If no automatic control equipment is available to take care of additive additions, much closer control could be expected if the acid addition rate were reduced or stopped altogether during these additive additions.
7. A method was found for quickly and accurately establishing the proper control instrument settings for a given set of operating conditions.

In this instance satisfactory operation of the pH control system was obtained by mechanical maintenance and improvements in the pH cell sample system, acid pump, acid lines and others.

Acknowledgment

The author wishes to thank the many persons who assisted with this work, particularly J. C. Vogt for his contributions to the mathematical analysis and J. M. Studevant for computer operation.

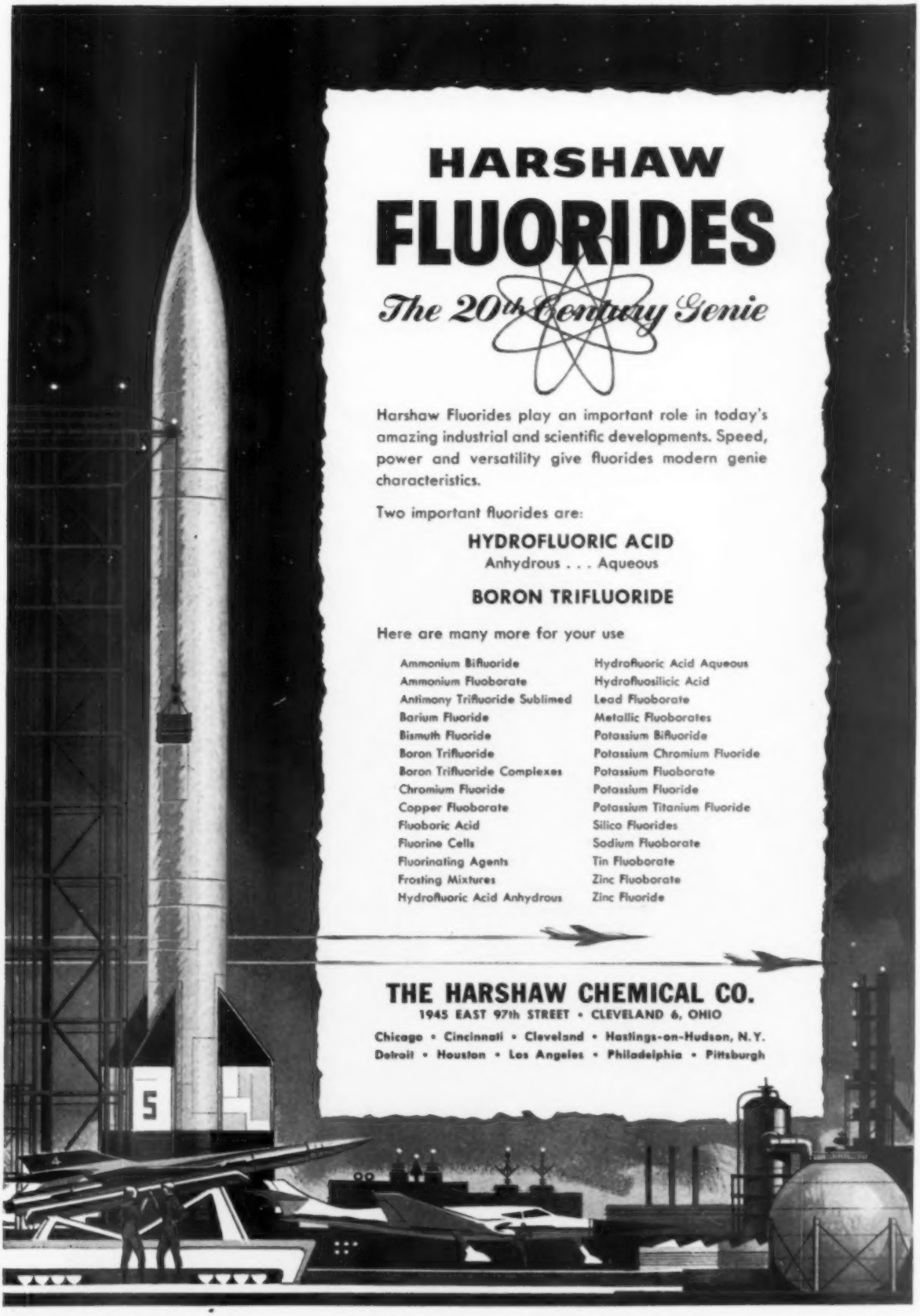
★ ★ ★

AUTOMATION Cuts Wax

Moulding Costs, Increases Purity

The Houston Sinclair Wax Plant has recently placed into operation a Greer continuous wax moulding machine that replaces the conventional, high-operating cost equipment. In this new unit, liquid wax is metered into coated stainless steel pans which pass through a chilling tunnel where the wax is solidified into cakes by circulating chilled air at about 25 F. The slabs emerging from the chilling tunnel are deposited on a traveling belt which transports them to automatic packaging equipment. The packaging room is air conditioned, with white terrazzo floor, and white ceramic tile walls. The wax is not handled during the molding or packaging stage.

Molder has a capacity of 7500 lb of wax per hr and the weight of individual cakes is uniformly controlled to 10 lb each. The installation is the latest word from a sanitary standpoint, and the packaging room has the appearance of a modern air conditioned kitchen.



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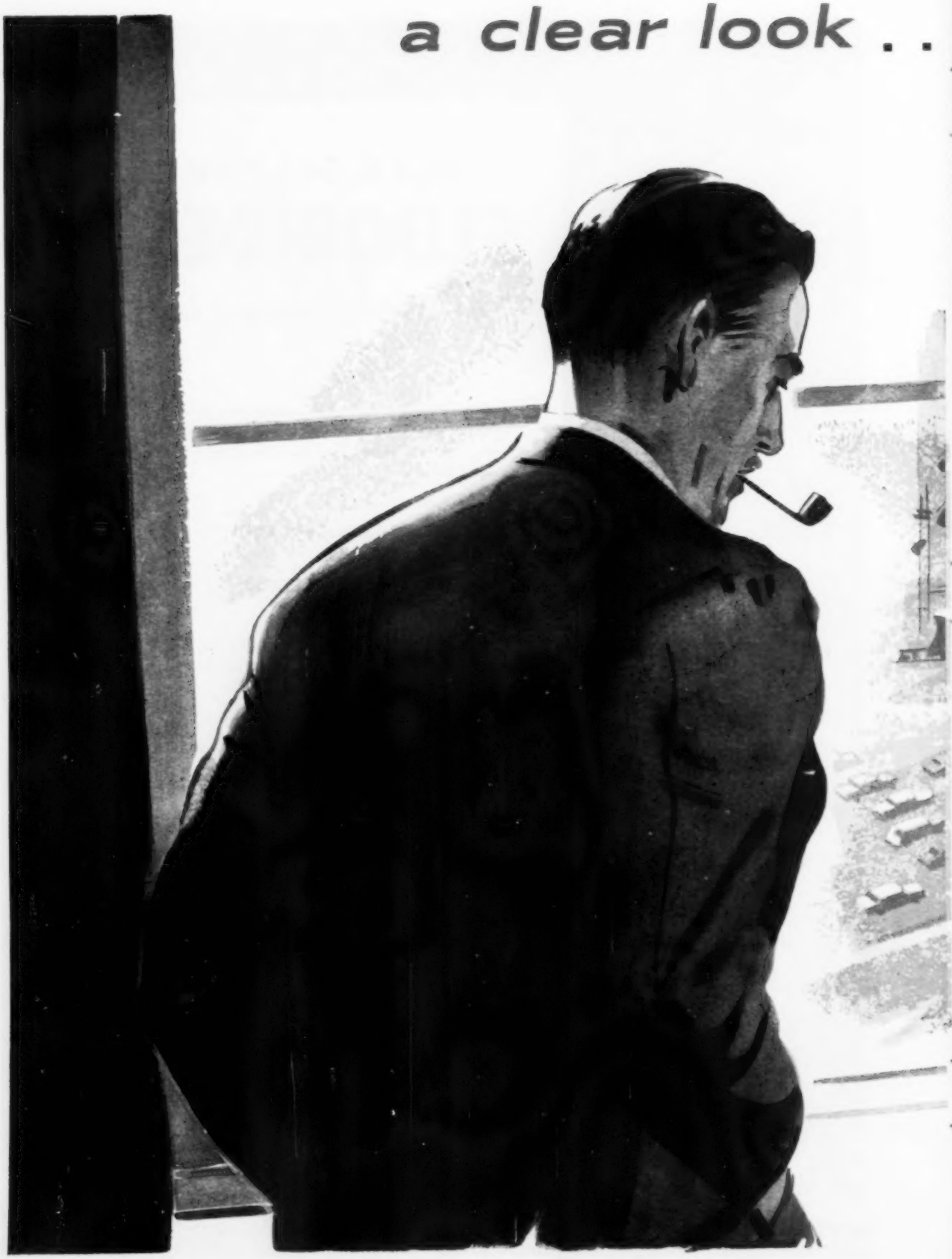

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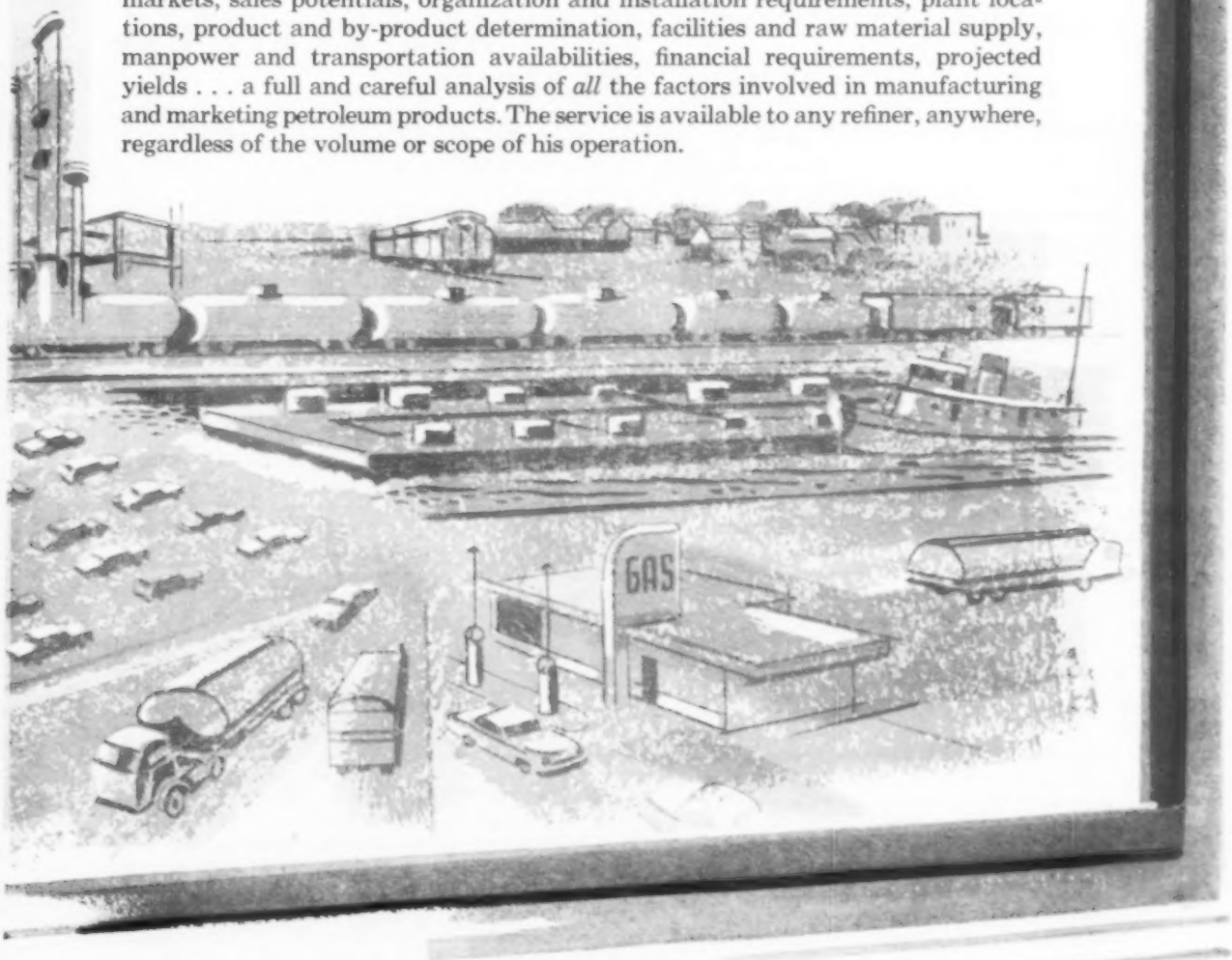

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Automation 57

PART 1 | **Automation in Refinery Product Blending** — a series on concepts, equipment, and applications in the production of refinery end products

CONCEPTS IN AUTOMATIC CONTINUOUS BLENDING: The Tools and Their Use

Lawrence Lowy
Proportioneers, Inc.

AUTOMATION is a word to evoke varied response today. It is receiving wide attention in all phases of our economy.

While the term means different things to different people, we can all agree that, in a word, it conveys the reason behind this twentieth century industrial revolution. Man's continual drive for a higher standard of living with fewer and fewer work hours reaches a new plateau with automation — the integration of machine or processes with each other, into fully automatic and often self-regulating systems.

It is not the purpose of this article to define and review automation, but rather to examine the contribution made towards this by feeding and blending systems development in the process industry field and particularly in that of petroleum.

Automatic Control in Process Operations

In petroleum refining, considerable attention and emphasis has been given to the various process phases —crude distillation, cracking, reforming, polymerization, alkylation, etc. Automatic control from crude feed to the pipe stills on through to rundown tankage has been refined to a point where its acceptance and application is no longer questioned. However, it is only recently that the remainder of the manufacturing phase has been given its proper consideration in terms of automatic control.

To a fully automated process, it is necessary to utilize the concept of the ideal plant, i.e., the automatic factory operating without human hands and primarily governed by electronic "brains" — one in which raw material flows in one end and, in a continuous flow, comes out the other end as finished product of acceptable quality.

We have this, *to a degree*, in most refining operations today. From crude tankage (note the required holdup of tanker or pipeline receipts) the oil goes through the process to become finished *component* stock. Depending on the process through which it was run, we now have, as a result of a fully automated phase, cat cracked, straight run, reformate, alkylate, bright stock, cylinder stock, bunker, asphalt, etc. From this point through to finished consumer product, motor fuel, avgas, jet fuel, kerosine, heating oil, lubes, the continuous flow concept is almost completely ignored — or has been until recent years.

Just as the housewife mixes her cake batter or salad dressing, so the refiner — on his large scale operation — puts his various ingredients or components together. Quantities of many thousands of barrels of various gasoline base stocks, or hundreds of gallons of lube oil or pounds or fractions of a gallon of additive are fed into so called batch mix tanks or kettles. The contents are then stirred or agitated to insure homogeneity, tested and released to finished product storage. From this hold up point, these products are then distributed to carriers or package filling operation — pipeline, tanker, barge, tank car or truck, drums and cans.

From a process phase engineered and made automatic to the Nth degree the refiner turns time backwards in his blending operations and thus returns to the "horse and buggy stage." This batch blending operation is a carryover from when the first stills were in use. It is not practical or is it logical.

Need for Efficiency in Blending

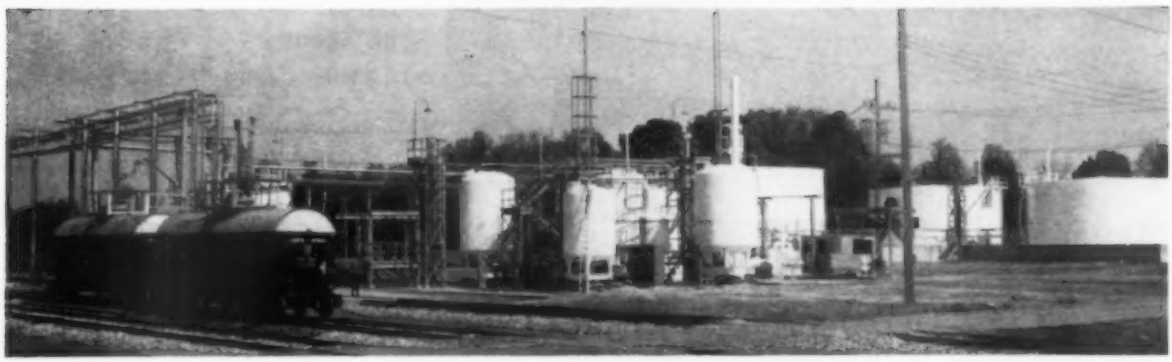
Many refiners are aware of this as efficiency becomes more and more necessary in order to produce economical operation. The mere fact that increased production requirements mean more storage is significant.

It becomes increasingly costly to turn out more product in terms of tankage and real estate and, from this standpoint, a close look at some of the methods by which continuous blending and proportioning is being carried on is justified. There are, of course, many other considerations, too.

The quantities involved in batching of motor fuel for instance are of such magnitude that multiple tanks of medium size or a single tank of mammoth proportions is needed. In the former case this means considerable space, in the latter, the time to roll or mix a tank of this size becomes costly and, more important, time consuming. The time during which tank contents are held up for the various non-productive steps—pumpover, cleaning, test, await removal — also contributes a costly item in the form of inefficient tank utilization.

Finished product inventory is susceptible to changes in market requirements whereas provision for this same storage for base stocks allows for blending to any specification with little or no inventory holdup and loss due to marketing changes.

Another factor to consider is the labor involved in the batch method. Much of the metering and quality con-

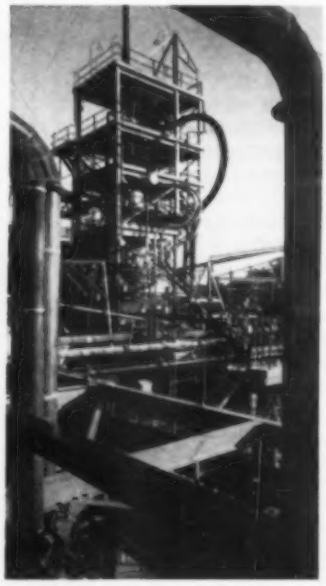


HERE IS the new Du Pont tetraethyl lead terminal at Beaumont, Texas. This latest addition to the rapidly expanding facilities insures an ample nearby supply, and prompt filling of orders from Gulf Coast refiners. The terminal contains complete modern equipment for storage and handling, and rapid dispatch of loaded TEL tank cars. The new terminal will be kept amply supplied with TEL by tank ship from the Du Pont manufacturing plant at Deepwater, New Jersey.

Three major expansions of Du Pont TEL facilities—already completed in 1957

Already this year Du Pont has opened a large new storage terminal, commissioned a new ship and opened a new manufacturing plant.

MV PETROCHEM, first ship to transport TEL compound in bulk, is another major addition to Du Pont's setup for delivering tetraethyl lead. Built primarily to supply the Beaumont TEL terminal, she is also equipped for transporting ethyl chloride and ethylene dichloride on northbound sailings. For maximum safety, the 6,000-ton tank ship is permanently compartmented, with solid bulkheads dividing the operational and cargo sections.



THIS NEW DU PONT TEL manufacturing plant at Antioch, California, was completed by Du Pont early this year. It was constructed to meet the needs of the fast-growing West Coast refining industry. Incorporating the most modern TEL manufacturing facilities in the world, it makes possible fast, short-distance shipments of California-made TEL to all West Coast refineries.

THESE THREE major expansions will increase even more the efficiency of the nationwide network of Du Pont TEL facilities. They complement the Chambers Works TEL manufacturing plant, the Du Pont Petroleum Laboratory, the five regional Petroleum Chemicals laboratories, the conveniently located rail sidings with loaded tank cars in 14 major refining areas, and the 12 sales-service offices. Like the wide range of services—technical, marketing, research, safety and operational—offered by Du Pont, the purpose of these installations is to help you get the most out of our additives program.

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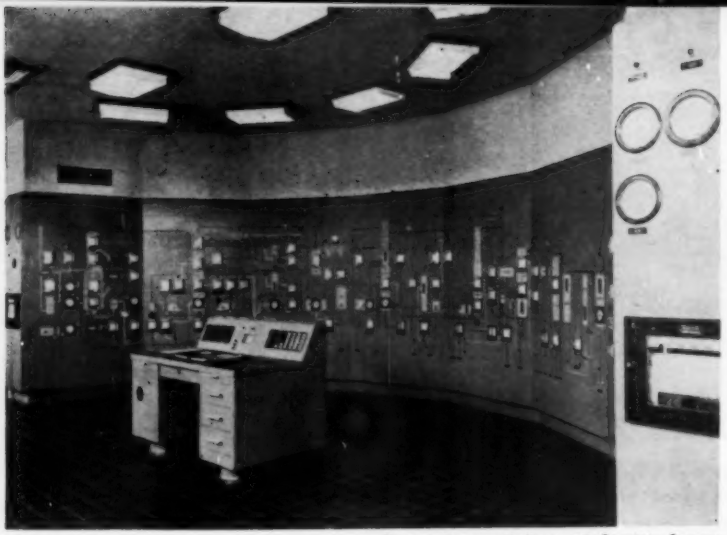
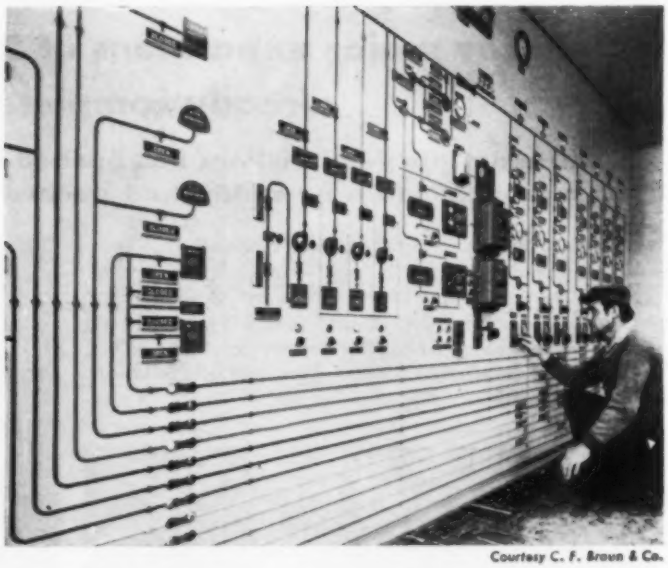


Courtesy Minneapolis-Honeywell Regulator Company

FIG. 1 & FIG. 2. **Just as concepts** of automatic control are applied to process units such as shown in the catalytic cracking and polymerization plant control room pictured below, they can also be used in storage and blending operations. On the left is a control panel that monitors and controls continuous product blending at Tidewater Oil Company's new East Coast refinery — the latest refinement in this phase of refining operation.



Courtesy C. F. Brown & Co.

trol must be left to the operator. The "human element" is always open to error. More often than not doctoring or "spiking" of batches is required. It even goes so far as to require the slopping of entire kettle contents on occasion.

Where expensive, toxic and explosive components, as in the case of butane, lube oil additives and TEL, are involved, close accuracy limits and safe conditions are more readily obtained with dependable, automatic metering equipment. It can mean considerable savings in the present practice of overfeeding additives to meet specification, and "then some to be sure." Light ends such as butane also constitute a source of loss — as well as hazard — on mixing and standing. The compensating action is to overfeed for insurance or adjust for expected shrinkage.

All of these factors — rising production, high costs of tankage and property, more critical quality control, excessive labor costs, repeated handling of product, rapidly changing markets, and quality give-away — are making it increasingly difficult to maintain profit margins to support the necessary activities and provide sufficient return. One of the most logical solutions is to streamline operations and still maintain or improve product. A sure point at which to start is the phase between process and finished product distribution. Automation or rather the making more automatic of this phase is what we shall be concerned with. For petroleum and petrochemical products it has a proved short-time payout with many added advantages.

Batch Blending

We need not dwell on batch blending. It is a time proved method of an intermittent nature requiring vessels, pumps, gagers, mixers. One could, with sufficient tankage, almost make a continuous flow through arrangement with suitable valving to divert batch production from tank to tank. This means many tanks serving no purpose other than as a temporary receptacle. Each must be filled, mixed, sampled, unloaded and while this is going on some other tank must be a step ahead of it and another a step behind. Clearly, as our growing needs call for more product, they also call for far better efficiency. We must seek ways to provide greater product uniformity, better quality control and reduction in material losses and rework.

Continuous Blending

Without a doubt, recent equipment refinements have made possible much of the rapid advance that has been achieved in continuous blending and feeding operations. For petroleum blending applications, flow is the most generally used measurement. Where other conditions can be maintained, i.e., fixed specification base stock, we can use rate of flow with dependable accuracy and repeatability in combining various streams to produce a specification end product. Certain volumetric flow devices are dependable for accurate readings within plus or minus 0.2 percent provided calibrated checks are included. Gravimetric feeders of a continuous type are accurate within plus or minus ½ of 1 percent by weight. With these tools the problem then becomes one of determining how to best combine and control them to produce the desired straight flow through operation.

Flow Measurement Devices

At this point let us just review the flow measurement devices most commonly used in the petroleum industry for they contribute the most critical information in any blending operation.

Any combination of equipment going to make up such a system is only as accurate and dependable as the components and the one most susceptible to error is the meter or measuring device. As mentioned before, accurate meter

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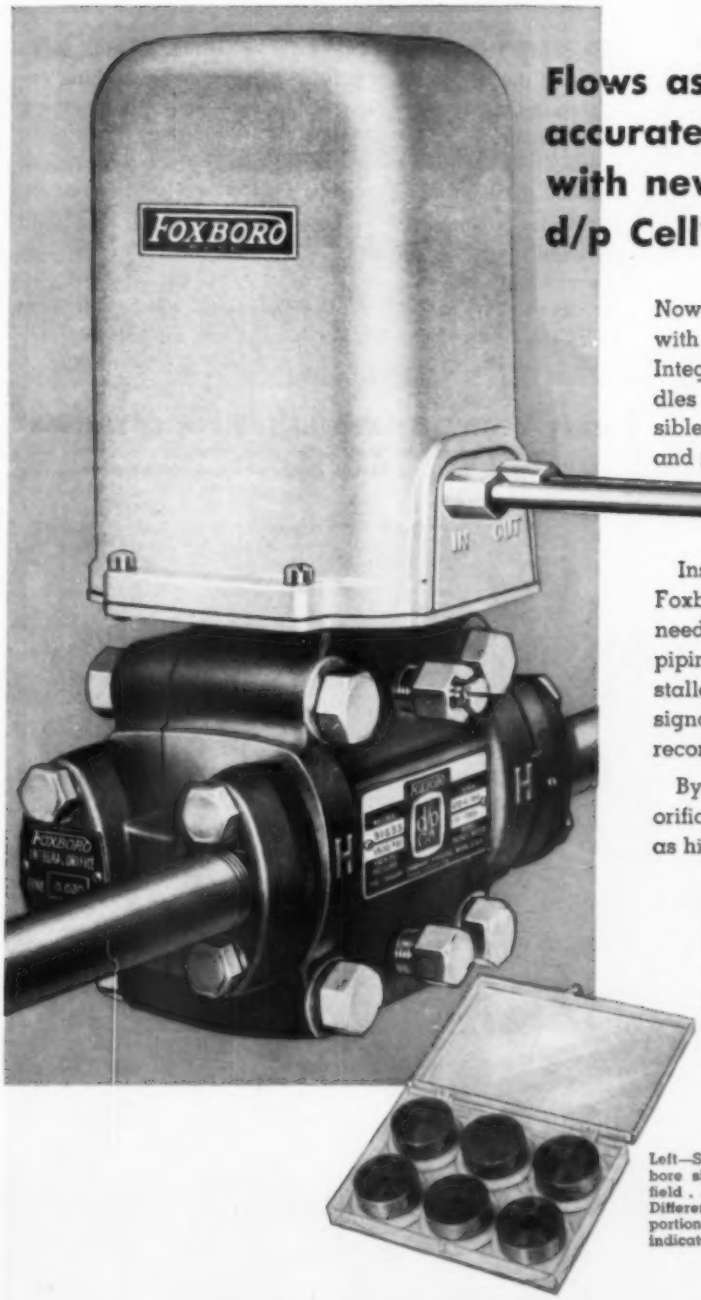

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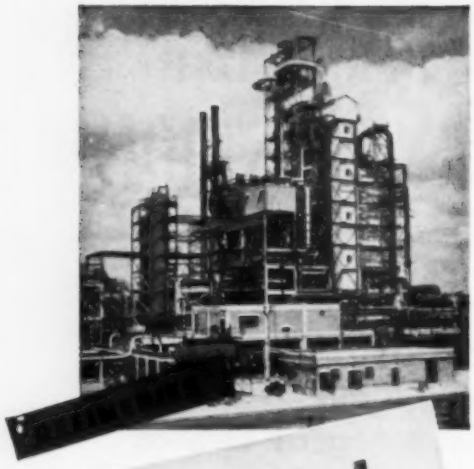

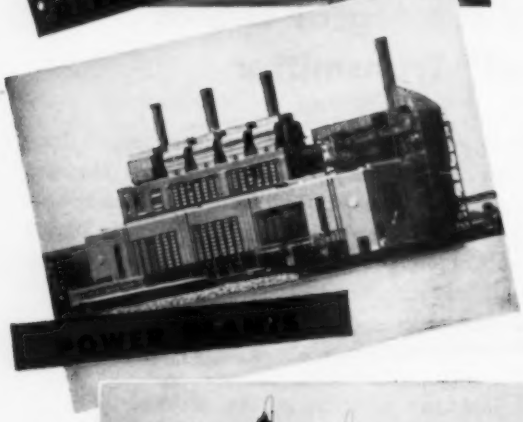

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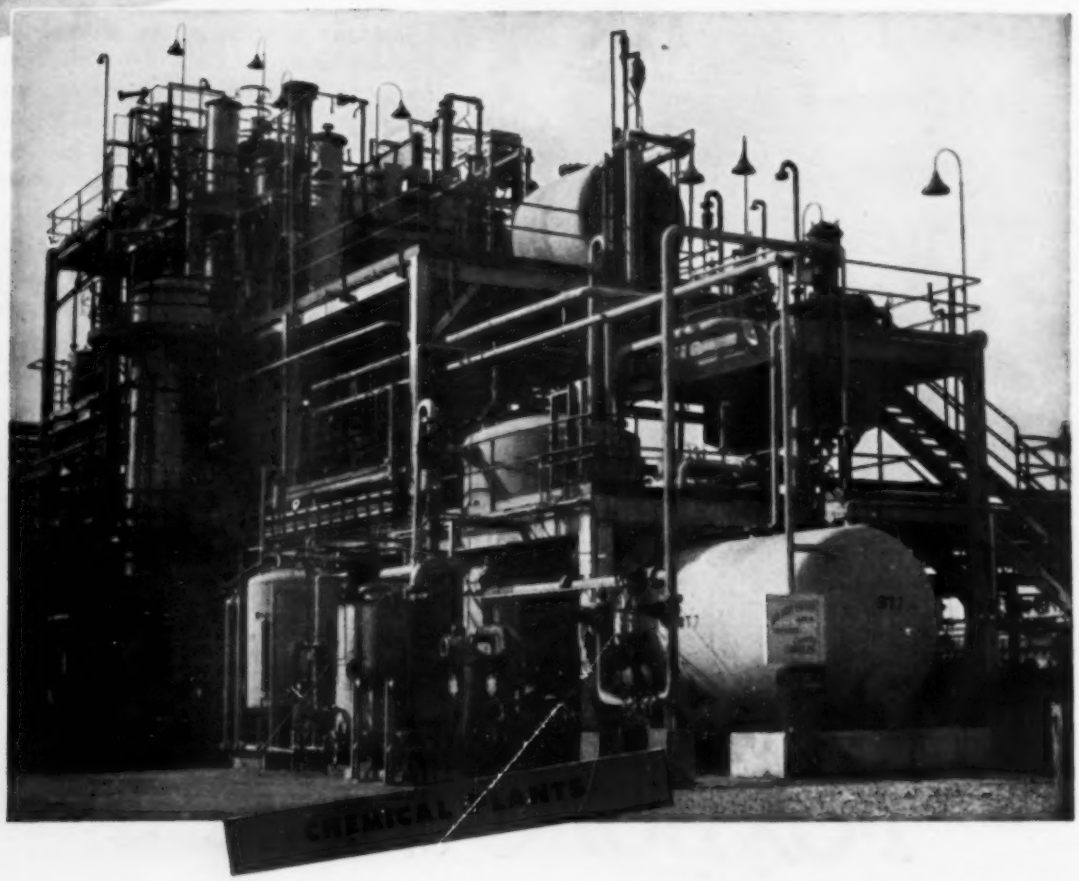

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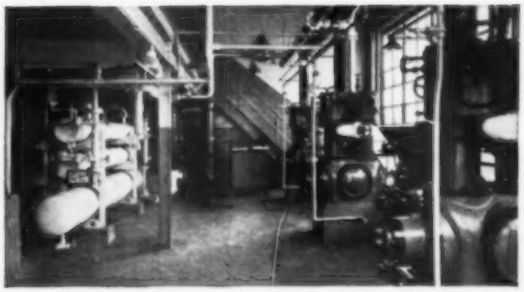

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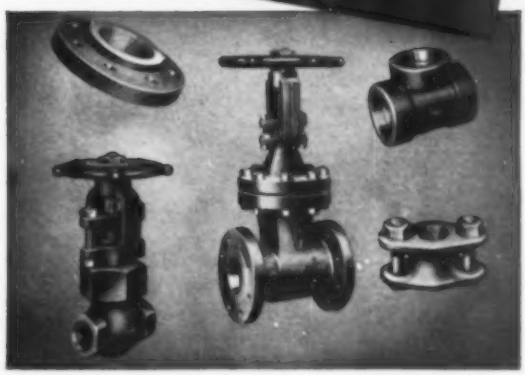

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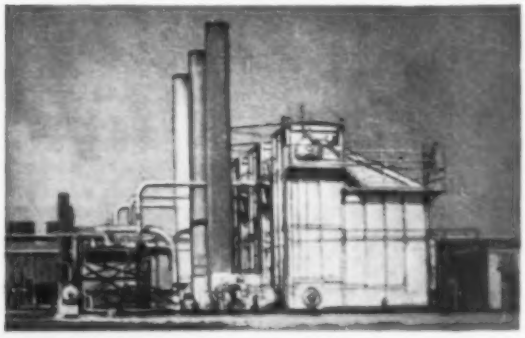

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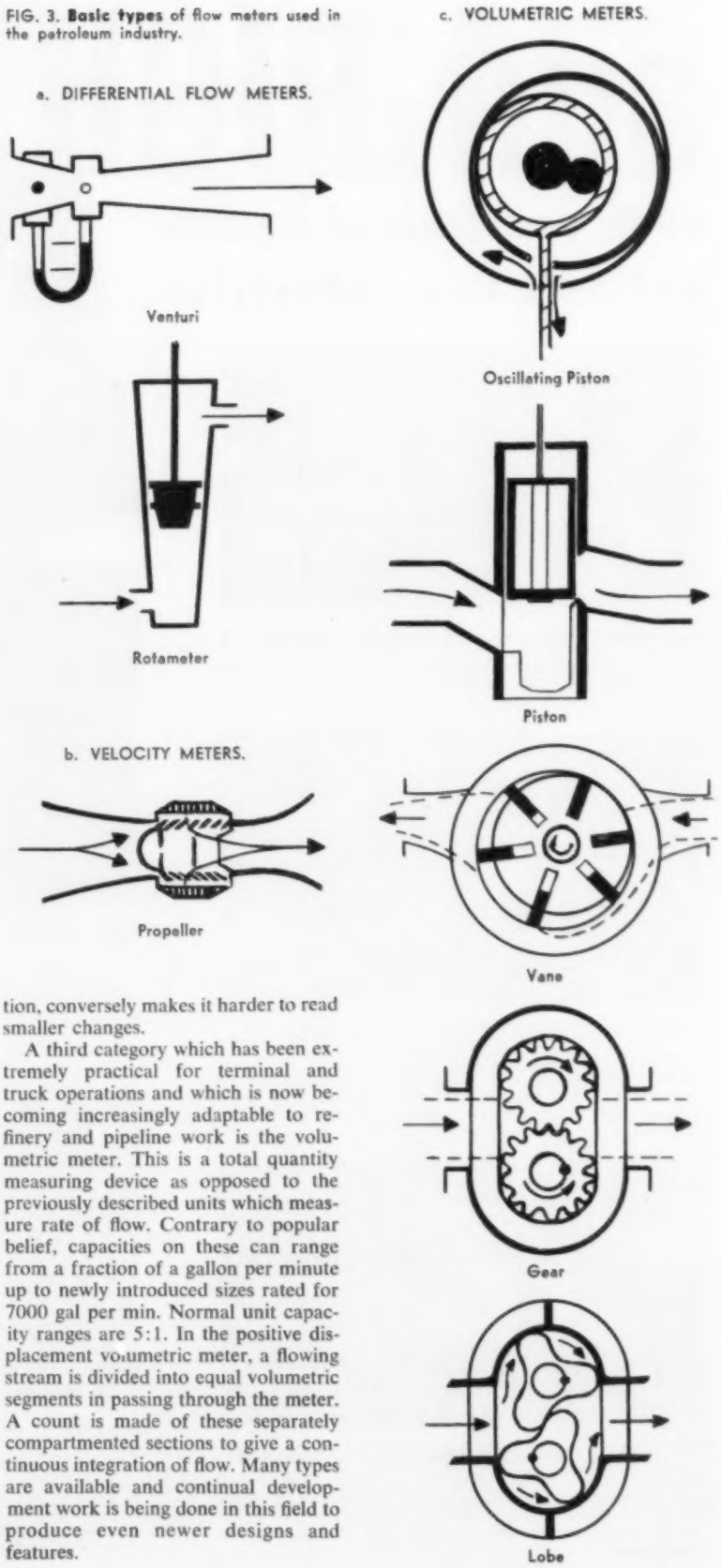
devices are available today. However, there must be means incorporated to check and calibrate the meters in use at any time to determine any drift or misoperation that may occur which could throw the system out of phase. Since this is a process dependent primarily upon maintaining proper flow conditions, the primary source of control is the flow meter.

While other analyzer elements such as viscosity, gravity, octane, Reid vapor pressure, etc., are available, they have not reached the stage where they can always be dependably used for control purposes. In most cases, they will suffice as indicators or recorders by means of which manual adjustment can be made, but the transition from the manual to the automatic operation has still to be developed to a point where it will produce dependable and repeatable accuracy. As a result most blending operations are determined by laboratory preblending for specification and then, maintaining constant specification base stocks, establishing percentage of each component to produce desired specification.

Meters in common use in the petroleum industry today are of three types, shown in Fig. 3. One is the differential type, i.e., the Venturi or Orifice type in which a fixed area is maintained and a variable differential is produced or the area meter or rotameter, as it is commonly called, in which fixed differential is maintained and variable area is produced by means of a bob moving within a tapered tube. Another type is the meter in which the velocity of a moving stream turns a free clearance propeller or turbine to directly drive an integrator or cut lines of magnetic force or interrupt an ultrasonic beam. Our flow formula, Q (flow) = AV in which A is area and V is velocity, shows the relationship between velocity, area and flow. Both the velocity meter and the rotameter type differential unit lend themselves to linear scale reading because of the aforementioned formula. Where area or velocity is varied we have a directly proportional relationship between it and flow. However, in the case of the differential meter, we are measuring a change in head or differential and we actually have a square root function to remove from our formula in order to get a flow reading ($V = K\sqrt{2gh}$). This is being successfully done, of course, and means considerably more accuracy within the upper ranges of the differential produced for the particular meter under consideration, as a much smaller change in differential and consequently flow can be measured by this means. The lower end of the scale, being a logarithmic function, conversely makes it harder to read smaller changes.

FIG. 3. **Basic types** of flow meters used in the petroleum industry.



A third category which has been extremely practical for terminal and truck operations and which is now becoming increasingly adaptable to refinery and pipeline work is the volumetric meter. This is a total quantity measuring device as opposed to the previously described units which measure rate of flow. Contrary to popular belief, capacities on these can range from a fraction of a gallon per minute up to newly introduced sizes rated for 7000 gal per min. Normal unit capacity ranges are 5:1. In the positive displacement volumetric meter, a flowing stream is divided into equal volumetric segments in passing through the meter. A count is made of these separately compartmented sections to give a continuous integration of flow. Many types are available and continual development work is being done in this field to produce even newer designs and features.

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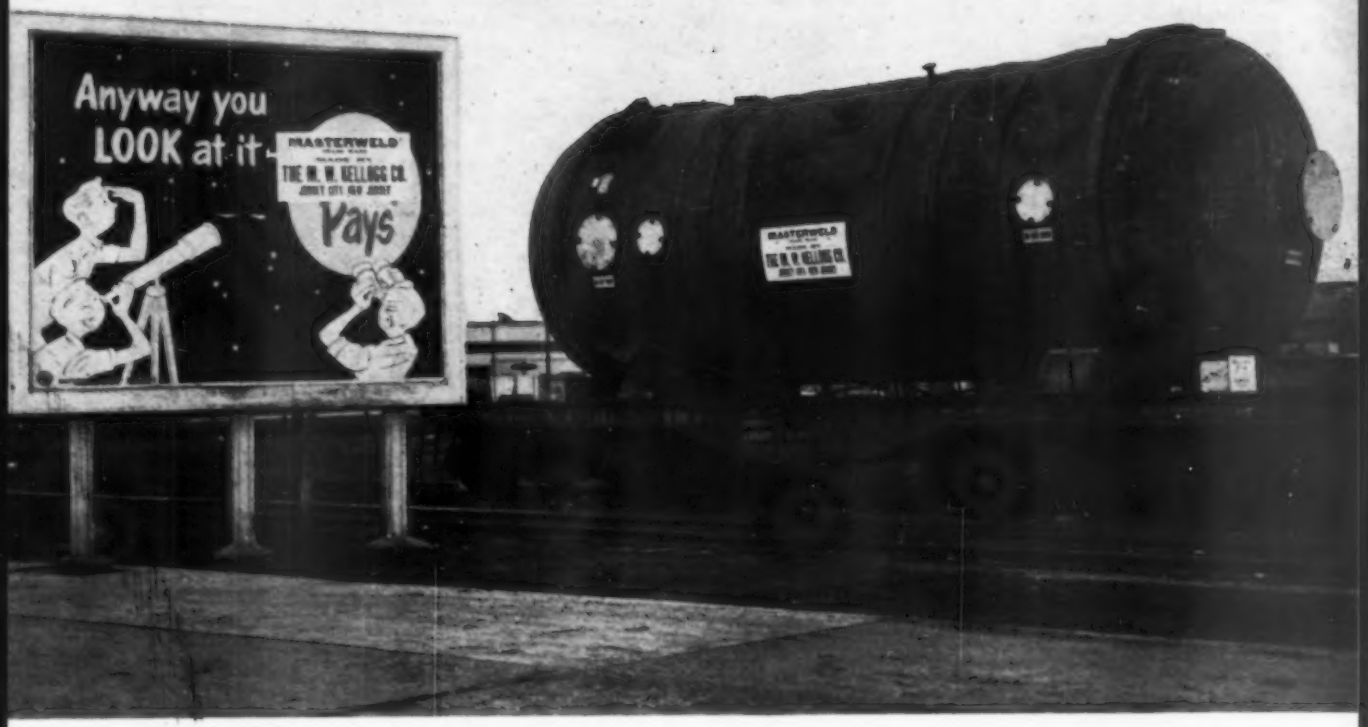

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*With apologies to Nations Safety Council Inc. for the temporary defacement.

The Author

Lawrence "Larry" Lowy is a popular and well-known expert in the field of product blending. A prolific writer in addition, he has authored many articles for this and other publications.

Larry holds both a bachelor's and master's degree in Mechanical Engineering. He graduated from Rennsaeler Polytechnic Institute in 1943, earned his master's from Stevens Institute of Technology in 1950, and is a registered professional engineer in New York State.

Mr. Lowy has been with B-I-F Industries for 10 years, and is now regional manager for Petro-Chemical Sales.

Volumetric Meters

The types most often found in petroleum work are shown in Fig. 3 and we will briefly describe them.

A design commonly encountered utilizes the oscillating piston principle. The meter consists of a chamber containing inlet and outlet ports. The measuring element is a single slotted cylinder or piston which slides or oscillates along a division plate separating inlet and outlet. An incoming liquid face causes the piston to roll as it moves trapping the liquid as the inlet port is closed off, and releasing it as the outlet port uncovers. Piston motion is guided by a central piston shaft riding within a cylindrical guide built into the meter body.

The piston motion is transmitted through an enclosed gear mechanism, into any integrator to register total flow for control purposes. An electric contactor can be mounted in the spindle housing to transmit an electric pulse for each revolution. Or, a balanced pilot valve can be driven by spindle rotation (suitably converted to reciprocating motion) to alternately feed operating fluid (air, steam, hydraulic) to the drive end of a feeding device.

Another type of piston meter actually uses pistons in the normal sense. Double or quadruple acting pistons are driven by the fluid. Piston action controls operation of slide valves for controlling admission and expulsion of fluid, and actuates meter register drive shaft.

Clearances between moving element and the stationary housing (normally the meter chamber) will determine to a great extent the accuracy obtainable with the positive displacement meter.

An important factor here concerns whether the seal between moving parts is of a capillary type (in which the liquid itself serves as the sealing medium), or whether it is the directly-packed sealed type as represented by the piston meter (in which moving parts actually come in contact to seal off the measured volume).

In the former design, viscosity of the fluid and degree of clearance determine the amount of fluid which will slip by adjoining sliding parts. As viscosity increases, slippage decreases. In the latter, brass liners and leather cups on pistons, as well as rotary face to face valves, effectively seal the fluid so that no slippage results. This, of course, imposes limitations on size, complexity, and friction load.

Another class of positive displacement meter, the vane type, uses evenly spaced vanes in the periphery of a rotor, (Fig. 3c). In one style these rotate about a fixed cam as fluid moves through measuring chamber. A roller at the base of each vane rides the cam and follows its contour about the cycle causing radial movement of vanes.

A point in the rotation is reached where two successive vanes are fully extended, thereby forming a filled chamber of precise volume. For each rotor revolution, four of these closed chamber measurements are produced. The action is smooth and continuous, producing no arresting of liquid velocity.

Another type uses a horizontal plate in which four vanes are fixed. The upper vane section rides a slotted conical rotor offset from the vertical so that fluid is trapped in a pie shaped section as the entire assembly rotates.

Still another in the same class has measuring elements consisting of four half-moon shaped vanes equally-spaced about a centrally mounted rotor, Fig. 3c. Since the meter is mounted in the vertical plane (most meters are mounted horizontally), the entering stream impinges on the first vane.

As this stream drives the rotor, it also tends to rotate the vane to seal off a definite volume between itself and the following vane going through the same movements. Continued movement of the rotor causes the vane to revolve and release the fluid to discharge. The vane then passes a close clearance section, which positions it ready to receive the next volume of liquid.

The two-spiral fluted rotor meter, representative of the gear or double rotor type, provides a measuring space between lobes of the rotors. Close clearances are maintained and sealed by the capillary action of the fluid.

For some applications two positive displacement pumps, in series, furnish a measurement arrangement. By maintaining a zero pressure drop across the downstream pump it actually acts as a meter. The excess capacity of the supply pump, or upstream unit, is manually set to maintain an upstream pressure equal to that in the manifold or downstream section. The second pump, or metering element, is manually adjusted for rate. More details will be given on this in the section dealing with the type of blending to which it applies.

Metering in Blending Operations

Basically, we desire to minimize the conversion of material from one state to another and to reduce handling and storing wherever possible. These are wasteful operations; yet quality control is such that to avoid it we must have a continuous analysis of our product stream and report back to continuously confirm the fact the product is on specification. In brief we need to continuously monitor the blending operation.

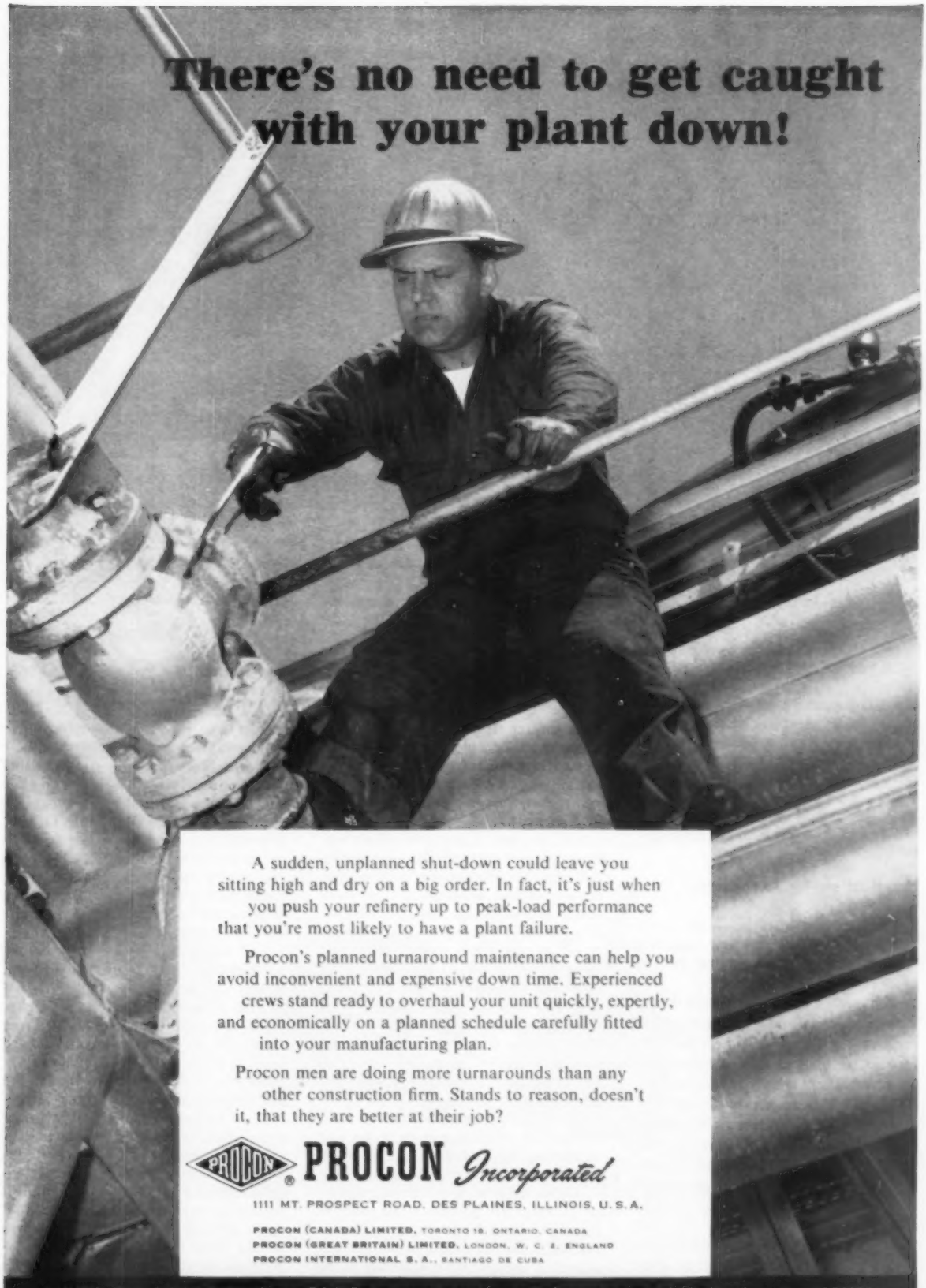
The keyword is monitor. It is significant, for without a dependable check and warning arrangement we have no report on how the blended product compares with the checks that have been established. The term used to describe this continuous check on our so called "mechanical brain" or monitoring device is "feedback or closed control loop."

"Feedback" Defined

Feedback is a report or signal representative of a measured value such as variable flow of a stream. The signal is compared with a reference signal. An upset is imposed on this comparator section should any disagreement exist. As a result a corrective action is transmitted from the comparator to a governor or adjusting device which will bring the measured variable back to match the master or reference signal. In simpler terms and by means of an example, we can show exactly what is meant.

If you will refer to Fig. 4, you find a meter in a main line stream. If the meter is directly connected so as to mechanically feed a rotary signal to a comparator device and we drive our reference signal into the other side by means of a mechanical rotary signal, we then have a point of comparison of the two input speeds. It is then possible to sense any differences that develop. Should this matching be incorrect, a mechanical device will be actuated to move away from a set point and position some controlling element to bring the metered signal in line.

The device might be a control valve in the line which will tend to throttle to speed up or slow down the meter and bring the slave speed in line with the master speed. This is a very basic part



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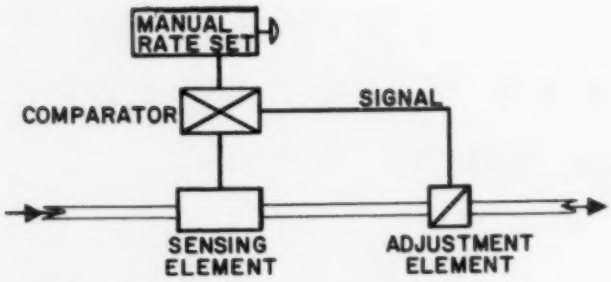


FIG. 4. **Direct-connected** flow control devices.

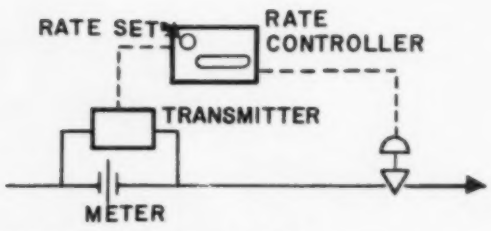


FIG. 5. **Differential** flow control device.

of dependable continuous flow operation. It need not be mechanical comparison and transmission but pneumatic, electrical or electronic. As long as we can accurately analyze or measure our stream in the terms which will determine the desired end product specification and continuously compare it to a desired value, we can produce the closed loop. By this means the metered signal is compared to the desired variable reading and adjusted if it deviates from desired value.

The above covers a fairly standard procedure used in present day instrumentation for individual streams. The standard flow rate controller operates in this fashion. In Fig. 5, we have the metering element shown as a differential unit. The signal, converted and adjusted for square root is delivered to the comparator instrument where a manual adjustment has determined the set point or desired value to which the metered value must be matched. If the two points do not match, then a change in the pneumatic output signal will adjust the control valve to bring the metered rate in line with the manually set rate.

Application to Automatic Blending

The next step is to review the application of the principles just described to the automatic blending of two or more streams.

One way, of course, would be to have a series of flow rate controllers each individually adjusted for rate. As in Fig. 6 we have four streams each set to maintain a given *flow rate*. Assuming all instruments stay "onstream" we have a fairly effective system. However, difficulties can be encountered. First there is no integration of all control settings from a common source, i.e., an original setting is made—should it be necessary to change any one stream, it then becomes necessary to change all streams in order to keep them properly in balance as far as percentage settings are concerned. To

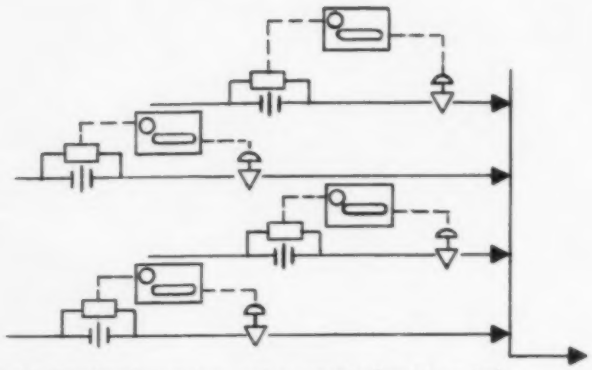


FIG 6. **Blending** four streams, each on separate flow rate control.

illustrate, suppose the settings are such as to produce a 10, 20, 30 and 40 percentage blend for the four streams at the rates set. If we now want to increase our total output or the capacity on any one stream, we must readjust the settings on all controllers in order to maintain the same percentage values for all streams.

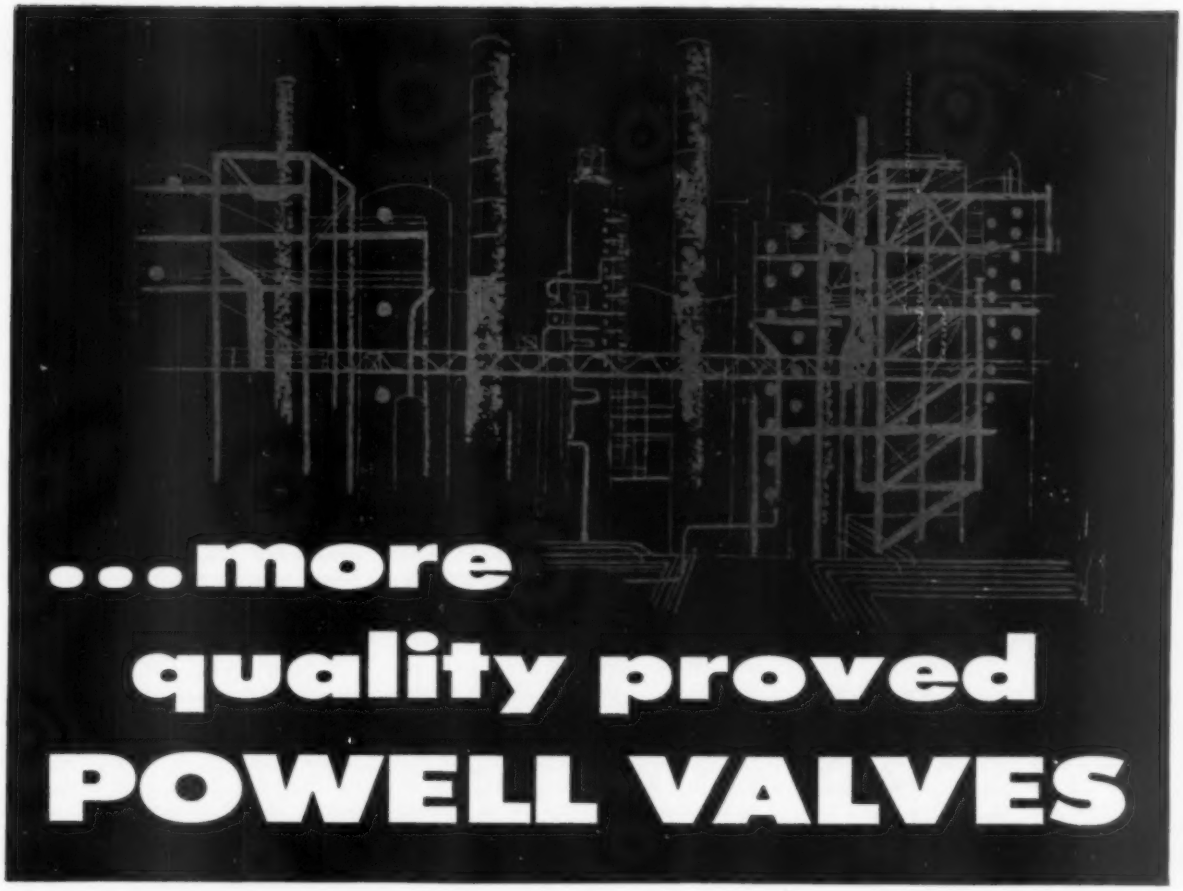
Still another factor will effect our blend, should accuracy be a very critical item. Each controller or flow rate control system produces a sine wave action in controlling. Since each stream is operating independently, fluctuations are completely out of phase and they do not make up any overage or underage necessary to bring the control valve back on control. Result — an error of adjustment goes unrecognized. Since we are matching a manually set condition against an actual condition, any swing away from the so called "set-point" acts to bring the control back in line with the established condition. A recognition of what goes on in the way of feeding more or less material to attain this condition is not stored in the system — later on we will refer to this as a memory feature. The control merely senses a departure and moves to maintain the set point condition not reflecting the corrective quantity in the way of excess or shortage of material to bring about this repositioning.

Mechanical vs Pneumatic Control

Now let us go one step further and, instead of using a pneumatic transmission as we have in the previous illustration, use direct mechanical connection and gearing for our system. For ease of discussion and greater metering accuracy we will now shift from the differential type of meter to the positive displacement type and use the mechanism rotary spindle output from the meter, representing gallons per minute, as our input to the gear type differential shown in Fig. 7.

For simplicity we will assume we are blending two systems. Each of the meters will drive a separate side of a geared differential device. For purposes of ratioing, the primary or large flow side will use a gear ratio device to step down the meter spindle representation of flow so as to match the secondary or smaller flow rotary signal.

Now we have a device, in terms of the mechanical differential, which actually can remember how much it has over or underfed in order to maintain or bring the control back to set point. In operating correctly, the two differential gears are driven in opposite directions at the same speed and the spider or differential rotates relative to its own center, but remains stationary relative to the center of the driver gears.



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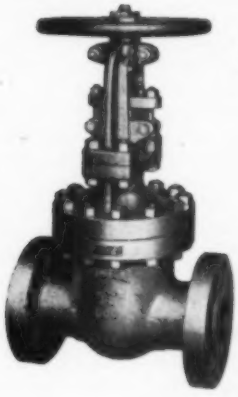


FIG. 6003 SS—Alloy Steel Gate Valve for 600 Pounds W.S.P.

FIG. 3061—300-Pound Steel Swing Check Valve.

FIG. 1563G—Gear Operated Lubricated Plug Valve, 150 Pound Steel.

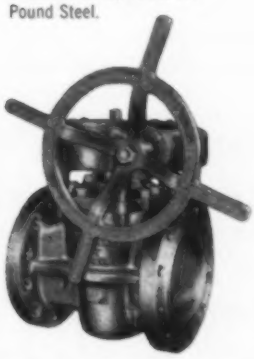
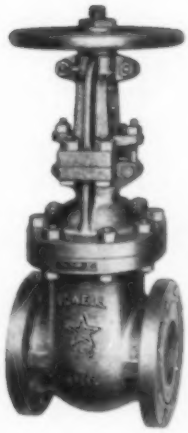


FIG. 1503—150-Pound Steel Gate Valve.



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This is because one drive side is going as fast in one direction as the other side is going in the opposite direction. Any over or under signal from either meter representing a shortage or excess flow in either line will cause one of the two differential gears to move slower or faster than the other and will actually cause the spider to move around the periphery of the differential. In so rotating, it also causes the shaft to which it is pinned to turn. This, in turn, can be used to either reposition the valve requiring the corrective action or, through a transducer, produce a pneumatic signal to bring a control valve into play. Now the action is to reverse the trend which caused the upset, i.e., the valve position will tend to overfeed where an underfeed condition existed so that the loss or underfeed condition which existed prior to the corrective action will be compensated for in bringing the system back on the set point.

Thus, we have improved on our closed loop continuous system in bringing in the so called "memory feature."

But, there is one significant disadvantage here. Where the meters drive the differential and the differential in turn directly controls the valve, we impose a load on the meter in attempting to directly position the control valve. Where we can augment this with a Servo system such as the air controller, the problem is eliminated. However, there is another slight drawback in that we are attempting to use our meters for the pacing or master as well as sensing function. This does not lend the flexibility and sensitivity that might be desirable for certain applications.

The Master Control System

In the next step, the rate setting function is divorced from the meter and is applied by a manual or automatically controlled master rate setting device.

For this we refer to Fig. 8 in which we have a constant speed motor whose output can be manually or automatically controlled to represent an overall blend rate. If we feed this into one side of the geared differential unit and require that the meter input to the other side match it, we have a completely integrated, non-meter loaded, memory device. Any number of components can be handled in this fashion. The meter now becomes merely a continuous measurement transmitting device which can be matched against a percentage delivery from our adjusted constant speed source.

Later on in this series we will actually describe blending operations in which this sort of equipment is used.

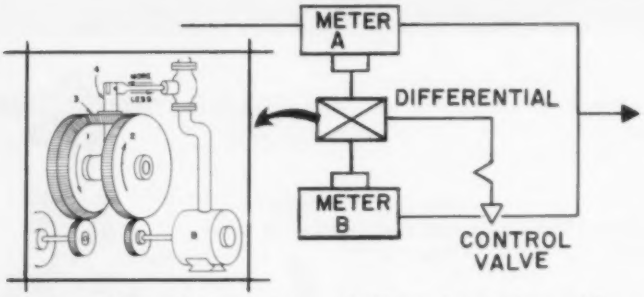


FIG. 7. **Differential** flow controller, used with a positive displacement flow meter.

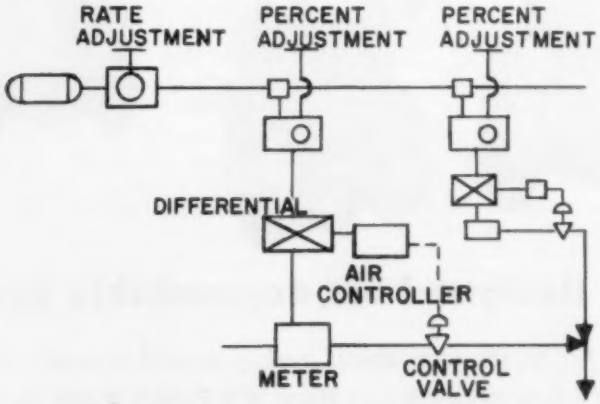


FIG. 8. **Addition** of a constant speed motor that is either manually or automatically controlled to represent the overall blend rate to one side of the differential unit results in an integrated, non-meter loaded memory device.

Ensuring Accuracy

Thus far we have covered the various steps in closed loop control which can produce an in-line blending arrangement in varying degrees. All of this is based upon dependable accuracy of the meter — subject to check at any time —and the ability of the system to recognize and upset condition incapable of correction and thereby "fail safe," i.e., shut down, go into recycle, store or memorize the over or underfeed continually being delivered.

The first consideration, calibration at any time, can be accomplished a number of ways. Normally, where flows are 800 gal per min or less, it is practical to use a conventional prover tank or test meter run in series with the meter under test. For larger metering facilities, a nest of parallel small test meters can be used—each having been checked out with a prover tank. An even more practical approach is a length of pipe which is essentially a calibration tank of small diameter and infinite length laid on its side and referred to as a calibration loop.

If such a section is carefully constructed and measured for capacity it can be incorporated into the piping scheme. At any time the stream for a meter under check can be diverted through this loop and back into the meter line. Equipped with pig or scraper barrel and start and stop trip switches, there is no limit to calibration capacities.

An important consideration in the calibration scheme is that such means be incorporated to make the check at any time, preferably during a run.

The "fail-safe" concept is also of paramount importance. Provision should be built into any continuous blending system to show, by stoppage, redirection of flow or memory, any inability of the system to maintain established conditions. This might be caused by air, electric or mechanical failure, weather conditions, line or strainer plugging, etc.

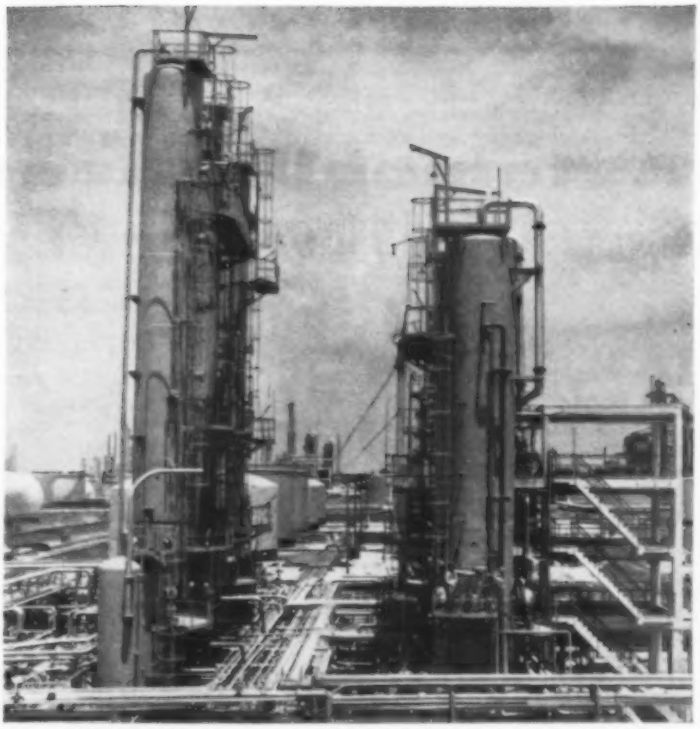
Conclusion

With such features as we have covered, an in-line blending system can be relied upon to monitor present conditions reliably and continuously.

These then are some of the tools with which we will be working in subsequent articles applying stream blending to specific applications in the petroleum field.

Thus far the quantitative devices have covered only those used for relatively large volumes — the base stocks that go to make up many of the blending operations carried on today.

The next article, to appear in the October issue, will deal with devices used in feeding additives. ★ ★ ★



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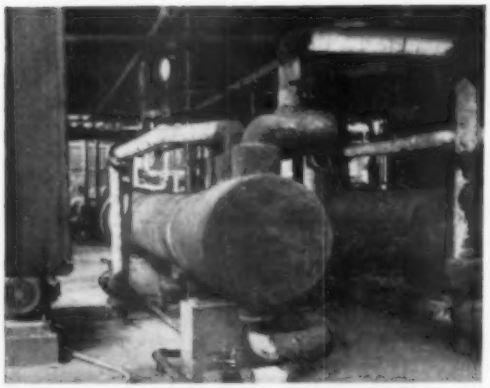
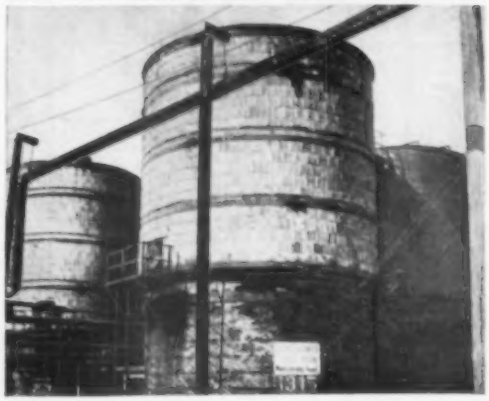
Experience spurs use of Monel for handling caustics





Heat exchangers (left) — Here's a preheater that is exposed to contaminated caustic entering the regenerator tower and to pure caustic leaving. Despite severe conditions, the preheater is giving trouble-free service. Shell and tubes are Monel alloy.

Agitators (lower left) — In this large agitator tank at an eastern refinery, bottoms and sides up to 6 ft. were replaced with Monel alloy. A wise choice. Monel alloy has proved to be the most economical material to use for this service.

Experience like this has led to the use of Monel alloy for a variety of other caustic processing units: reboiler tube bundles, hot caustic lines and caustic storage vessels, to name a few. In petrochemical plants using caustics, Monel alloy guards product purity.

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C-63

THE PROBLEM OF

Automobile Gear Lubricants

New chemicals are carrying the terrific tooth loads; torque converters may give tomorrow's answer

C. J. Boner
Chief Research Chemist
Battenfeld Grease and Oil Corporation

WITH the introduction of the hypoid gear in differentials of automobiles (about 1926) the necessity for something other than straight mineral oils as a rear axle lubricant became apparent. Due to the cooperative effort of additive manufacturers, automobile producers, governmental agencies, and oil companies, composition limits and evaluation methods for what were first called Hypoid Gear Lubricants and later, as the U. S. Government designated them, Universal Gear Lubricants, were formulated and made available.

The first such lubricant used was a lead soap-active sulfur type. This proved quite satisfactory for the cars of that vintage in which the gears were subjected to the torque of much lower horsepower engines than at present.

Since the extreme chemical activity of this type of additive was not desirable in all types of service, another type of additive consisting of sulfur-chlorine compounds was introduced a few years later. Such lubricants proved satisfactory for the lubrication of hypoid gears over a wide range of operation conditions.

Also, gear lubricants containing load-carrying additives containing sulfur and chlorine were suitable for both transmission and differential gears, whether of hypoid or other types. Consequently, in 1942 the U. S. Government adopted a Universal Gear Lubricant covered by Federal Specification VV-L-761. In 1944, the United States Army Ordnance adopted a gear lubricant with identical requirements but designated as 2-105. Fluids of this type have since been designated as Multi-Purpose Type Gear Lubricants.

During World War II it was found that the subject lubricants were inadequate for high torque-low speed service in certain units. Consequently some revision of the requirements was necessary, but in general the lubricant designated as MIL-L-2105 was of the same general type as before. Since rear axle fluids conforming to the above specifications gave quite satisfactory service for both army and civilian uses, the subject of change of such gear compounds was rather dormant for a number of years.

Why a Stepped-Up Gear Lubricant Is Needed

Within the past three or four years it has been increasingly evident that

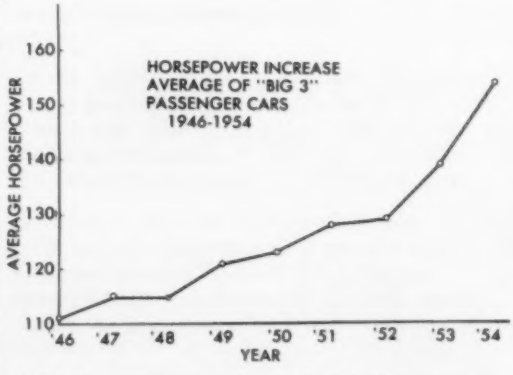

FIG. 1. Average horsepower increase for "big 3" passenger cars, 1946-54.

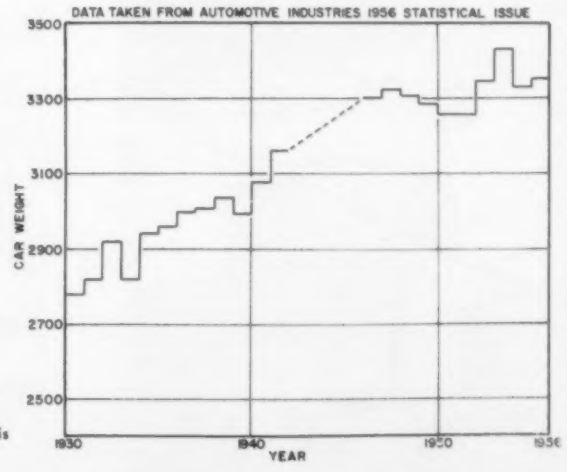

FIG. 2. Car weights are going up, as seen from this chart for 1930-56.

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Multi-Purpose Gear Lubricants of a higher level of extreme pressure resistance were required. In spite of the small gallonage of such fluids compared with other petroleum products required for automobile transportation (Table 1), an inadequate rear axle lubricant may mean failure of a vehicle.

Heinen[1] has listed as follows the reasons why an upgraded Multi-Purpose Gear Lubricant is a necessity:

1. Increased output of modern engines has caused greater power to be put through the rear axle. This is quite evident from Fig. 1.
2. Car weights are going up slowly, but steadily, see Fig. 2. This means greater inertia loads.
3. Car heights are going down, see Fig. 3. This in turn means greater offset and smaller, rather than larger, differentials.
4. Rear axle temperatures are rising, see Fig. 4. This is confirmation of the fact that the other trends are affecting the work being done through the rear axle.
5. Better highways are available on which higher average speeds are possible. These probably result in longer periods of high temperature operations.

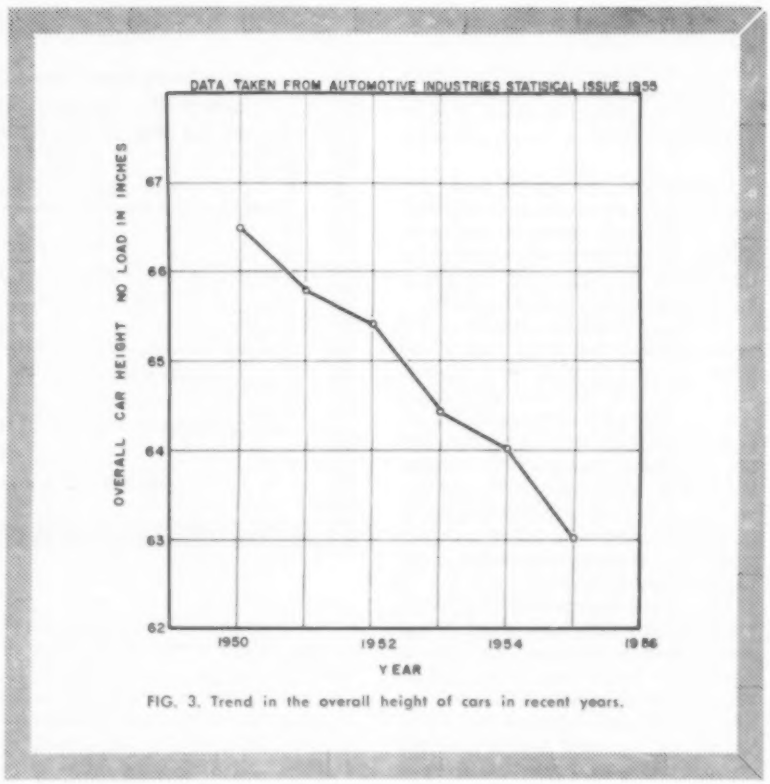

FIG. 3. Trend in the overall height of cars in recent years.

The above changes in automobile designs and powering have coincided with a record of service failures in rear ends of certain newer models of cars. Since such failures indicated that Multi-Purpose Gear Lubricants which were available to the public did not supply the necessary chemical films needed under the peak torque conditions of high-powered automobiles, the manufacturers of such cars tried to solve the problem in different ways.

One major automobile producer formed a phosphate film on the gears during production and then used Multi-Purpose Gear Lubricants which were of the MIL-L-2105 grade. While this prevented most rear end failures it did not stop the search for an improved lubricant.

Other manufacturers chose to use, as the initial factory fill in the differential housing, an active sulfur lubricant which was afterward drained, following a break-in period, and replaced by Multi-Purpose Gear Lubricant.

Still another group recommended an active sulfur fluid for the life of the car. One difficulty with this procedure is that this latter lubricant is not satisfactory for truck operations. Then if service stations are called upon to provide an active sulfur gear lubricant for passenger cars they must also provide a Multi-Purpose type for trucks. Such a procedure is not desirable because of the extra expense involved in stocking two lubricants of the same general type and also because of the possibility of misapplication.

Further, Noll[2] points out that "lead soap-active sulfur lubricants have also been reported to cause wear of antifriction bearings under certain high load, high temperature conditions, which may limit their use in new designs of the future."

The possibility of rear axle failures due to deficiency in the lubricant may well be traced to manufacturer's recommendations that no change be made in the differential fluid during the life of the car. During 1955 approximately 70 percent of the automobiles produced were made by companies who made this recommendation and in most cases no drain plug was provided in the differential housing.

It is only necessary to point out the possibility of changes in the fluid and the possibility of contaminants to see why better protection against failure will result if the lubricant is renewed at intervals. At the temperatures to which rear axle fluids are subjected (Fig. 4), oxidation will occur in the best of such lubricants. This will result in thickening which will decrease the efficiency as a lubricant and a heat transfer medium. Also, there will be some depletion of the load carrying ability of the mixture so that the factor of safety is lowered.

The greatest danger in continued use of gear lubricants is probably from the presence of contaminants, however. Smith[4] states "Finely divided solid matter is invariably found in used transmission oils. If such contaminants continued to accumulate indefinitely the oil would eventually begin to act as a grinding paste." Also, even with the best inhibitors present, some rusting will take place and the rust will add to the solids present.

Conditions To Be Met by a Universal Gear Lubricant

Perhaps the problem of a Universal Gear Lubricant will be clear if the extreme demands on such a fluid are cited.

First, it must protect the gears at high speeds where sudden shocks occur. At such times the temperature of the points of contact of the gears is quite high, perhaps even reaching the melting point of the metal. At such times the additives in the lubricating fluid must form solid films which will substitute for the oil films which are ruptured. These anti-welding films may be a product of the gear metal and one of the chemical elements in

the additive. For example, iron chloride, with a melting point of about 1240 F, or iron sulfide, with a melting point of about 2180 F, will form. If lead soap is present in the fluid, lead sulfide may form as the anti-welding film.

Formation of these films must take place instantaneously to prevent welding of the metal surfaces, otherwise scoring of the gears will result. This then points to a lubricant containing additives of great chemical activity.

As the anti-weld film reaches a certain thickness the shear forces will break off part of this. With further activity of the lubricant this action may be repeated. Since the film in question involves both the additive and the gear metal, eventually a substantial loss of metal occurs. One of the secrets of a good gear oil additive is that it be chemically active to a degree, but not too active so that metal loss will be excessive.

The second requirement of a Multi-Purpose Gear Lubricant is that it prevent excessive wear in truck operations where high torque conditions are combined with high fluid temperatures and low speeds. Due to these low speeds the anti-weld film can be put on at a more moderate rate than in the case of automobiles.

Summarizing, the ideal Multi-Purpose Gear Lubricant for automotive vehicles should have sufficient chemical activity to protect gears against both speed-shock conditions and low speed high torque conditions. At the same time, the lubricant must not be so active as to cause corrosion of the parts.

Evaluation of Improved Gear Lubricants

When hypoid lubricants were first introduced, attempts were made to evaluate them by bench tests. However, for many years dependence for measuring the value of the lubricant has been dependent upon full scale testing equipment supplemented by road tests.

Don't miss the 1957 Instruments and Control Equipment Directory beginning on E-7 of this issue.

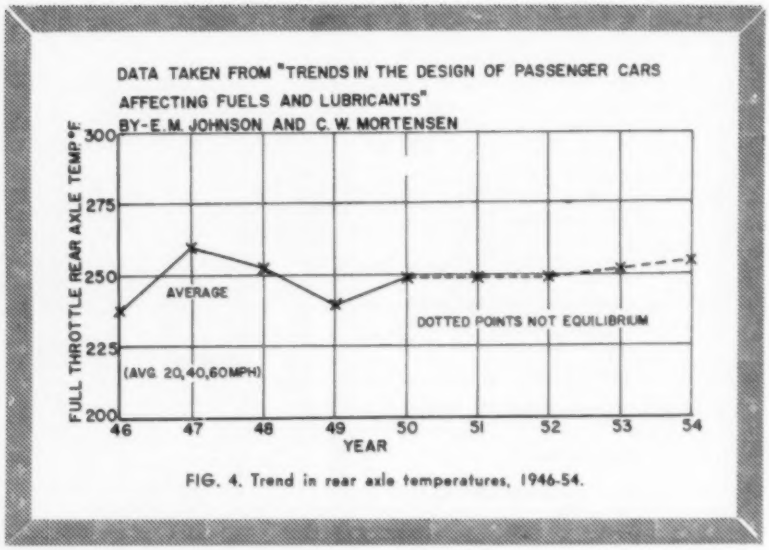

FIG. 4. Trend in rear axle temperatures, 1946-54.

While the motor car manufacturers conduct some of the subject tests on their proving grounds, much of the field testing has been centered under the supervision of a Coordinating Lubricants Group. This group is made up of representatives of the oil industry, additive manufacturers, and of the armed services. The thought is that it is desirable to arrive at compositions and evaluations which will satisfy both the automobile producers and the agencies charged with procurment of satisfactory gear lubricants for various U. S. services. This, then, will permit marketers of lubricants to supply a uniform product to all users and through all channels.

Solution of the Problem

Improved gear oil additives are available which, according to road tests conducted at Yuma, Arizona, a few months ago, should be acceptable to all concerned. However, there still seems to be a question as to the maximum high speed passenger car requirement.

This need may be reconciled by starting with two different lubricants, one of relatively high and the other of low load carrying ability. A sliding scale of extreme pressure capacity could be arrived at by various blends of the two above fluids. Once the maximum performance level has been arrived at, a test procedure could then define this.

It is hoped that a maximum level can be defined which will satisfy all concerned and as Noll[2] has suggested "set the level at a point sufficiently high to take care of all passenger car requirements for at least five years in the future."

Future Automobile Transmissions

While the solution mentioned above may satisfy the immediate requirements for automobile gear lubricants, the car of the not too distant future may pose a different problem. There will no doubt be further increases in horsepower. If this goes far enough, gears can be dispensed with and a fluid clutch or hydraulic coupling could be used. Otherwise, with the powerful torque of higher horsepower engines, when the lower gears are used, the limit of the tires to maintain traction will be reached. Raviolo[3], in considering the changing character of the American Automobile, states, "I can visualize a large engine with a hydrodynamic torque converter and a reverse gear in place of today's complex assembly with a three-speed and reverse gear box." The problem of automobile gear lubricants would then be solved but also replaced with a demand for a still better torque converter fluid.

TABLE 1—Approximate 1955 Usage of Petroleum Products in American Automobiles

Motor fuel, all	54,329,744,000 gal
Motor oils, all	880,624,000 gal
Gear oils	49,200,000 gal
Type A fluid	25,747,000 gal

— Credit C. M. Heinen

References:

1. Heinen, C. M., Paper, Independent Oil Compounders Association, Chicago, September 24, 1956.
2. Noll, C. R., Paper, Lubricating Committee, Division of Marketing, API, February 28, 1956.
3. Raviolo, Victor G., Lubricating Committee Meeting, Division of Marketing, API, May 24, 1956.
4. Smith, A. C., *Scientific Lubrication*, Vol. 8, No. 11, 18-24 (1956).

★ ★ ★

REFINING Personals

John N. C. Cameron has been appointed account manager, petroleum chemicals division, E. I. duPont de Nemours & Company, with offices in Dallas, Texas. He was formerly laboratory manager for the Gulf Coast.

E. W. McNealy, superintendent of The Texas Company's Lockport, Illinois, works, has become assistant general superintendent of Port Arthur, Texas, works, in the refining department. **H. A. Lord,** superintendent at the Lawrenceville, Illinois, works, becomes superintendent of Lockport works. **Ray Powell,** superintendent — special assignments, in the New York offices, becomes superintendent of Lawrenceville works.

Harold M. Smith has been named new chairman of the Petroleum Division, American Chemical Society. He has been a member of the society since 1924 and has been active in local section activities and in the Division of Petroleum Chemistry.

Walter I. Weed Jr. has been promoted to assistant supervisor of Tidewater Oil Company's 7 state and Hawaii western oil purchase and exchange department. He was formerly an operating assistant in the department.

Arthur B. Kent has been appointed chief chemist at Sun Oil Company's Marcus Hook refinery. He succeeds **George E. Reese,** who has retired. Since January, Kent served as special assistant to **Walter C. Huffman,** superintendent of refining.

D. L. Winsett, former superintendent of the Ohio Oil Company's refinery in Robinson, Illinois, is the new refinery manager. He succeeds **H. E. Handy,** who has been in ill health for several months and has been granted a medical leave. **B. B. Miller,** formerly the assistant superintendent, succeeds Winsett and **J. A. Coddington,** former senior engineer on the refining staff in Ohio Oil's general office, Findlay, Ohio, becomes assistant superintendent. Handy will assume other duties with Ohio Oil when he returns to the company.

David Christison of Woodbury, New Jersey, has been awarded a Sloan fellowship entitling him to participate in the executive development program of the Massachusetts Institute of Technology. Christison is assistant director of the technical department of Socony Mobil Oil Company's Paulsboro refinery.

Dr. L. H. Sutherland has been appointed section head in the research program of Escambia Chemical Corporation. Sutherland will be in charge of the analytical and certain of the process groups, and his activities will be divided between Cambridge and Newton, Massachusetts, where Escambia presently has its research and technical service facilities.

New top level positions in Magnolia Petroleum Company's refining division were made known recently with the announcement that **P. L. Smith** of Beaumont, Texas, became general manager of the division. **F. M. Graves** was promoted to assistant general manager, refining division, and **R. C. Adam** replaced Smith as manager of operations at the big plant. **W. M. Bradshaw** was named executive assistant.

John B. Clopton has joined Escambia Chemical Corporation and will devote his activities to commercial development and the sales of ammonia products and methanol. He was formerly with the plastics division of Monsanto Chemical Company at Texas City, Texas, where he was sales manager for monomers and raw materials.

C. E. "Gene" Davis, petroleum consultant, Kirkwood, Missouri, has been appointed a member of the board of directors of Commerce Oil Refining Corporation. He will also serve as a member of the Executive Committee and will act as part-time consultant to the corporation.

D. Glenn Morgan, Tulsa, Oklahoma, recently retired director of research and development, D-X Sunray Oil Company, has been retained by the Western Petroleum Refiners Association as consulting technologist.

John S. Patchin retired from The Atlantic Refining Company after 37 years of service. Prior to his retirement he was assistant plant manager of the firm's Philadelphia refinery.

Harry A. Logan Jr. was elected president of the United Refining Company at a recent meeting of the company's board of directors. **Fred G. Bannerot Jr.** of Charleston, West Virginia, was elected chairman of the board. Other officers were **John P. Wendell,** executive vice president and secretary and **Martin H. Smith,** treasurer.

E. H. Counts, superintendent of operations in the gas and gas products department of Sinclair Oil & Gas Company, Tulsa, Oklahoma, has been promoted to staff general superintendent of the department.

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For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

Spectrophotofluorometer. Ideal for quantitative assay, fluorescent analysis, and identification of compounds in solution throughout the visible and ultraviolet regions, instrument permits continuous activation of compounds and the measurement of the resulting fluorescence throughout the visible and ultraviolet regions.

It has been applied to a number of problems involving both identification and quantitative assay of many organic compounds which fluoresce with sufficient intensity under normal operating conditions so that 0.01 to 1 microgram per milliliter can be measured.

Instrument provides a ready means for surveying new compounds such as aromatic compounds in petroleum and coal tar products. *American Instrument Company, Inc.*

Circle number (41) on reply card.

Data Logged at 72 Stations. Datalogger, latest addition to telepulse equipment, will be installed in a large oil refinery. Liquid levels in 72 large storage tanks will be automatically logged each half hour with ⅛-in. accuracy.

Upon interrogation, this unit responds with a unique identification code corresponding to its address and then sends level in feet, inches and eighths. Digital transmission up to 1000 miles over one wire (earth return) does not degrade accuracy.

Continuous-supervision alarm circuits warn of dangerously high or low levels, and the unit prints these data in red. *Shand and Jurs, Electrical Division.*

Circle number (42) on reply card.

Newly Designed Pressure Transmitter. Model "P" Pressure Transmitter is a rugged yet highly sensitive unit, ideal for measuring pressures and for liquid level indication. Model "P" is capable of meas-

uring levels from 2 ft of liquid head and pressures to 100 psi, with a linear accuracy of plus or minus 1 percent. It is unique in that it provides the universal 3-15 psi signal for the controller. *Conoflow Corporation.*

Circle number (43) on reply card.

Test Bridge Simplifies Dielectric Testing of Plastics and Liquids. A test bridge has been designed specifically for measuring dielectric properties of sheet plastics such as bakelite, Teflon, and polystyrene, and for analysis of the electrical performance of oils. The instrument has been designated as the Type FT-VKB Dielectric Test Bridge. With appropriate accessories, it can readily measure the dielectric constant and dissipation factor of materials in either sheet or liquid form. At power frequencies the dissipation factor range can be extended to as high as unity by using a small range extension adapter. Capacitors and similar components can be checked as easily as materials. *Federal Telephone and Radio Company.*

Circle number (44) on reply card.

Fully Automatic Control. Industrial process plants for the first time can obtain fully automatic control through use of the RW-300 digital control computer. Shown in an artist's conception, the computer measures only 55-in. in overall length, is 29-in. wide, and 36-in. high. It weighs approximately 400 lb. The RW-300 has been

specifically designed to automatically control processes such as oil refining and a wide variety of other manufacturing processes. It may also be used as a tool by research laboratories in the process industries to explore the application of this new technology to new processes. *Ramo-Wooldridge Corporation.*

Circle number (45) on reply card.

System Detects Moisture Build-Up. Increased use of pneumatic-operated control instrumentation in industry has necessitated the development of an accurate, inexpensive moisture-warning system. American Instrument Company announces the Dew-Point Monitor System which detects moisture build-up in airlines of pneumatically-operated instruments. The system detects unfavorable moisture build-up when it approaches the danger limit, and then actuates an alarm.

The Dew-Point Monitor System is comprised of two devices: The Aminco Humistat, a precise humidity controller containing a sensitive electronic switch that actuates an alarm when a pre-set dew-point temperature is exceeded; a small plug-in type electric Hygrometer Sensing Element which senses moisture content changes instantly, and relays these changes to the Humistat. *American Instrument Company.*

Circle number (46) on reply card.

TV Solves Safety Problem. Closed-circuit television is now being used by Esso Research and Engineering Company as a pilot plant safety aid at the firm's Bayway, New Jersey, facility.

Hazardous atmospheres in the propane deasphalting pilot unit make it desirable for the shift foreman located in a nearby building to observe the area so that emergency measures may be taken if trouble develops or an operator falls ill.

A General Precision Laboratory television camera with wide-angle lens and enclosed in a protective housing is mounted to survey the critical area. The continuous picture of workmen on the job, transmitted by coaxial cable to a TV screen in the foreman's office 300 ft away, permits immediate action if required. A similiar picture appears on another receiver installed in the shift inspector's office. *General Precision Laboratory Incorporated.*

Circle number (47) on reply card.

Reactor for Oil Research. A new, low-power, nuclear reactor suitable for research laboratory use is presently under development by Nuclear Development Corporation of America. It utilizes heavy water (D_2O) as moderator and coolant. A thermal neutron flux of about 10^{12} neutrons cm^2/ sec is available near the core at the maximum operating power of 25 kw. *Nuclear Development Corporation of America.*

Circle number (48) on reply card.

Console Graphic Panel. Graphic panel represents the modern approach to process instrumentation. It embodies the latest advances in the field of graphic panel fabrication. Sloped console as an integral of

the panel eliminates the need for a separate operator's console. *Falstrom Company.*

Circle number (49) on reply card.

Temperature Sampler. Weksler Scoopmaster is a corrosion-resistant tank thermometer designed for use where chemical action of such compounds as aromatic hydrocarbons or petroleum products is critical.

The sturdy one piece cup case is molded of smooth, heat-resistant, nonsparking plastic wtih a low thermal conductivity. The 120 mil cup capacity meets the standard requirements of both the ASTM and the API.

Temperature ranges offered are from a low minus 40 F to a high 500 F. Graduations are permanently engraved on a 14 in., red-reading, wide bore tube. *Weksler Thermometer Corporation.*

Circle number (50) on reply card.

New Temperature Instruments. A new thermometer series including recorders, recorder-controllers, indicators and indicator-controllers has been introduced by Barber-Colman Company. Using large 12 in. easy-to-read charts, uniform accuracy over the entire scale is assured by the use of mercury-actuated sensing elements.

Control forms available include: Type 401, designed for applications where transfer lag and dead time can be reduced to a negligible value; type 402, two-position "anticipatory" time-proportioning control; type 403, multi-position control with dual single-pole double-throw (H_{CL}) switch action and many others.

The overall dimensions are 16¾ in. by 14 in. by 8⅜ in. The temperature range of the series is from —40 to +950 F. *Barber-Colman Company, Wheelco Instruments Division.*

Circle number (51) on reply card.

Hydraulic Fittings Tester. A "utility" version of the new Farris "Porta-Tester," weighing only 55 lb and self-contained, has been developed for at-the-site hydrostatic testing of valves, pressure wheels, piping, steam generators, pump cases and other process equipment. Pressures up to 3000 psi may be used in tests.

Portable unit is complete with four test-accuracy gages and 8 ft of hydraulic, flexible tubing. The pump handle folds flat for easy storage in the case. The unit can be used with water or other hydraulic fluids. *Farris Engineering Corporation.*

Circle number (52) on reply card.

Data Processing. Electronic data processing system manufactured by ElectroData, is installed by many refining companies. Single magnetic tape storage units, multiple magnetic tape unit (Datafile), tape control floating point, Datatron 205 computer are shown. In foreground, control

console with electric typewriter, high-speed tape punch and photoelectric reader. The internally-programmed decimal digital computer has a 40,800-digit storage capacity, with high-speed series-parallel operation. *ElectroData, Division of Burroughs Corporation.*

Circle number (53) on reply card.

High Accuracy, Easy Blending Control. The Blendtrol is a continuous flow blender and proportioner. It may be used to accurately maintain flow rates in a closed loop system, or to blend and proportion in an open loop system.

The Blendtrol is an electronic controller and may be remotely located to avoid unnecessary piping and thus substantially reduce installation costs. *The Jordan Company, Inc.*

Circle number (54) on reply card.

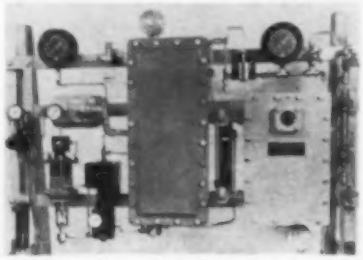
Partitioner. This Partitioner simultaneously performing a qualitative and quantitative analysis of any mixture of hard-to-separate components in a petroleum mixture, or solvents, liquid fuels, flue gases, etc., uses new method called "gas-liquid partition chromatography." In its ability to separate close-boiling point organic compounds, is the equivalent of a distillation column with an efficiency of more than 1000 theoretical plates. *Fisher Scientific Company.*

Circle number (55) on reply card.

New Pneumatic Actuators. Heavy gage pressed steel case, nylon reinforced Buna-N diaphragm and precision single spring construction are features of the new Super 70 control valves now offered by Black, Sivalls & Bryson, Inc. A diaphragm-spring pneumatic control valve, it incorporates high lift guided seats and contours to give improved capacity, valve characteristics and stability. *Black, Sivalls & Bryson, Incorporated.*

Circle number (56) on reply card.

Records Gage Pressures. Model 1157 instrument has been developed by the Shell Development Company and licensed to us for manufacture. Unit is for use on gasolines and other low-pressure hydrocar-



bons. Another model, 1158, is a modified version of 1157 and is for use on higher pressures and also to indicate proportions of binary mixtures of petroleum gases by a particular vapor pressure. Both instruments accomplish the recording by reading of the actual gage pressures of which only Model 1157 can be correlated with the Reid Vapor Pressure.

The vapor pressure is obtained by contacting the liquid phase with its saturated vapor while maintaining the sample at constant temperature, flow and level. *Hallikainen Instruments.*

Circle number (57) on reply card.

Electronic Infra-red Analyzer. The M-S-A Model 200 Lira has been designed to fill the need for a moderately-priced instrument for most continuous-flow chemical analysis problems. Instrument will solve the great majority of problems where there is a need for quick and accurate analysis of a single component in a simple or complex mixture of gases or liquids. It operates on the principle of direct deflection rather than electrical-null-balance. It can be used with an integral indicating meter as well as a recorder. *Mine Safety Appliances Company.*

Circle number (58) on reply card.

Recorder Has 1-Year Inking. Designed by the "Building Block Method" of instrumentation, Bailey multi-purpose recorder offers flexibility not possible in single-purpose instruments.

The user has 12 components to choose from in building up his instrument. These include (1) pneumatic receivers; (2 and 3) a-c and d-c electronic receivers; (4 and 5) pneumatic and electric transmitters; (6) integrators; (7 and 8) Bourdon helix and bellows pressure measuring devices; (9) program controllers; (10) running time units; (11) pneumatic controllers; and (12) electronic calculating units. *Bailey Meter Company.*

Circle number (59) on reply card.

Electron Microscope. A new 100 kv Electron Microscope (Type EM-100B) with many unique operating features including a hinged objective lens for quick change or cleaning of pole inserts, magnetic compensator, objective diaphragm with multiple apertures, and insert screen with binoculars for ultra-thin specimens, has been announced by the Instrument Division, North American Philips Company, Inc.

Guaranteed resolving power of the new instrument is better than 20 Angstrom. High resolution pole pieces permit continuously variable magnification from the control panel through a range of 5000 to 100,000 diameters. With diffraction pole pieces, the instrument magnifications are 1750 to 35,000 diameters. *North American Philips Company, Inc.*

Circle number (60) on reply card.

Fractometer Extends Gas Chromatography. New Perkin-Elmer Model 194 process vapor fractometer extends the widely-used and versatile and simple laboratory gas chromatography technique to continuous process stream analysis. The instrument can be easily set up to perform multi-component analyses on a wide variety of process streams in the petroleum and chemical industries. Unique features include a heat exchanger which insures thermal equilibrium between sample and carrier gas and a Teflon dryseal sampling valve which accurately meters the sample volume and avoids adsorption

effects of lubricants. Of particular interest to the petroleum industry is the fact that the programmer unit of the instrument contains no open switches, thus conforming to traditional safety standards for refinery control rooms. *Perkin-Elmer Corporation.*

Circle number (61) on reply card.

New Equipment

Portable Electrical Test. Portable 35-lb unit tests and calibrates motor starter overload relays, circuit breakers, protective relays, instruments, current transformers and related devices before outages or overloads occur. With this equipment, tests carried out by plant technicians and maintenance programs are facilitated. Consists of an adjustable autotransformer and a high-current loading transformer to provide a continuously adjustable output current. Unit also includes a multirange ammeter and a cycle counter, together with necessary leads. *Multi-Amp Corporation.*

Circle number (62) on reply card.

Portable Mass Measurement. Portability, simplicity of operation, and low cost are some of the reasons why the new Consolidated Electrodynamics Type 21-611 Mass Spectrometer is creating interest in the refining, chemical, petrochemical, and process fields. Weighing only 115 lb, this instrument will perform highly accurate batch or process analysis in the field or the laboratory. Operating within a mass range from 2 to 80 and with resolving power adequate for adjacent peak separation up to mass 35, it simplifies work through an improved scanning feature. Mass numbers appear linearly with time on a motor-driven dial making mass marking unnecessary. High sensitivity makes possible the detection of gas impurities in the low ppm range. *Consolidated Electrodynamics Corp.*

Circle number (63) on reply card.

Reversible Voltage-to-Digital Converter. The Epsco Model B Datrac is a high speed, highly accurate voltage-to-digital and digital-to-voltage converter. It is capable of converting unknown input voltages to digital coded form at high speeds and at precisely known times. The unit is reversible so that digital codes may be applied to the unit as inputs and proportional voltages obtained as outputs. Approximately 45,000 independent data conversions per second for an 11 place binary code can be accomplished with an accuracy of better than $\pm 0.05\%$ $\pm \frac{1}{2}$ the least significant digit. *Epsco Incorporated.*

Circle number (64) on reply card.

NEW LITERATURE

For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

Data Readout Counters. A new series of data readout counters for visual and electrical readout and electrical control is described in a brochure released by Veeder-Root. Each instrument, with its 5-figure capacity, provides 100,000 distinct circuit arrangements which lend themselves to the most exacting control and transmission requirements. This brochure is designed to acquaint the reader with these counters and their applications in the industrial control and data processing fields. *Veeder-Root Incorporated.*

Circle number (65) on reply card.

Steam Plant Equipment. Bulletin G-1308 (55) has been published by steam plant equipment manufacturer Yarnall-Waring Company. This bulletin covers the following: Blow-off valves, water columns and gages, liquid level indicators and recorders, expansion joints, steam traps, strainers and spray nozzles, research and manufacturing facilities. Each type is illustrated and its specifications listed. *Yarnall-Waring Company.*

Circle number (66) on reply card.

Testing Under Temperature. A well-illustrated brochure describes the new Model TC-4 line of temperature test chambers. Completely portable, unit is ideally suited to testing small items such as instruments, electronic components, organic materials, plastics, etc. The chamber has a test range from minus 75 F to a plus 600 F and controls to a tolerance of less than 4 F. *Statham Development Corporation.*

Circle number (67) on reply card.

Instrument Line. A complete brochure describing the Photovolt instruments for use in refining and processes is now available. It adequately describes pH meters, colorimeters, and fluorescence meters. In addition Bulletin No. 195 offers data on the new model 85 pH Meter which can be used also for acidimetric, redox and deadstop titrations. *Photovolt Corporation.*

Circle number (68) on reply card.

Controlled Volume Pumps. The Milton Roy Company has published Bulletin No. 457 "Controlled Volume Pumps in Petroleum Refining." This 16-page bulletin contains the latest techniques in controlled volume pumping and their applications in the petroleum industry.

Bulletin No. 457 describes actual chemical metering systems used in pilot and research plants, water treating, crude desalting, catalyst preparation, corrosion control and continuous grease preparation. Other chemical feeding systems are illustrated and described for metering product improvers and additives, sweeteners, dyes and antioxidants. *The Milton Roy Company.*

Circle number (69) on reply card.

Control Systems on Stock Basis. Volume users of control equipment turn to complete temperature control systems, integrated and housed in cabinets which save space and provide more convenient supervision. West Instrument Corporation has been producing fully wired and equipped units on a custom basis for users.

Now, according to Bulletin CS, several forms of complete systems are available on a stock basis as well as the tailored-to-fit variety. Systems come complete with appropriate instruments. *West Instrument Corporation.*

Circle number (70) on reply card.

New Low Cost Chamber. Tenney Engineering has made available a sheet introducing their Tenney-Mite mechanically refrigerated-cascade system. There is no installation charge and 3 low temperature ranges are available: —40 F, —100 F and —120 F. All Tenney-Mite specifications are given. *Tenney Engineering, Inc.*

Circle number (71) on reply card.

Differential Expansion Thermoswitch Controls. Fenwal presents a complete line of thermoswitch units (Bulletin MC-135A). This bulletin explains why these units control temperature precisely. Thermoswitch units are available as compression or tension operated types, allowing for extreme temperature overshoot or undershoot. *Fenwal Incorporated.*

Circle number (72) on reply card.

Two Laboratory Gas Chromatographs. Beckman Scientific has just issued Bulletin 711 on gas chromatographs, GC-1 and GC-2. The bulletin lists features, specifications, applications, temperature control, flow diagram of GC-2, and detailed information as to how the GC-1 and GC-2 operate. *Beckman Scientific Instruments Division, Beckman Instruments, Inc.*

Circle number (73) on reply card.

Viscosimeter Catalog. Fischer & Porter Company published a catalog No. 15A100 on its Viscorator, an auto-sampling device which continuously measures and records both the temperature and the temperature-compensated viscosity of liquids flowing in process piping. The Viscorator system is particularly appropriate to the petroleum refining industry.

Principal advantages of the F&P Viscorator, in addition to continuous measurement, are rapid response and the elimination of cumbersome temperature baths. *Fischer & Porter Company.*

Circle number (74) on reply card.

Bulk Loading Valve. A new bulk loading valve combining electrical control and manual operation, for controlling the flow of gasoline, kerosine, diesel, and fuel oils in remote metering systems, has been announced by the Automatic Switch Company. Solenoid valve is installed in the meter-line of a bulk loading terminal's remote metering system. The valve is designed to provide the terminal dispatcher with complete and absolute control of all deliveries. An electrical interlock incorporated in the standard loading valve prevents withdrawal until authorized by the dispatcher; unregistered deliveries are eliminated. Bulletin 8023 gives all dimensions and complete operating data on the valve. *Automatic Switch Company.*

Circle number (75) on reply card.

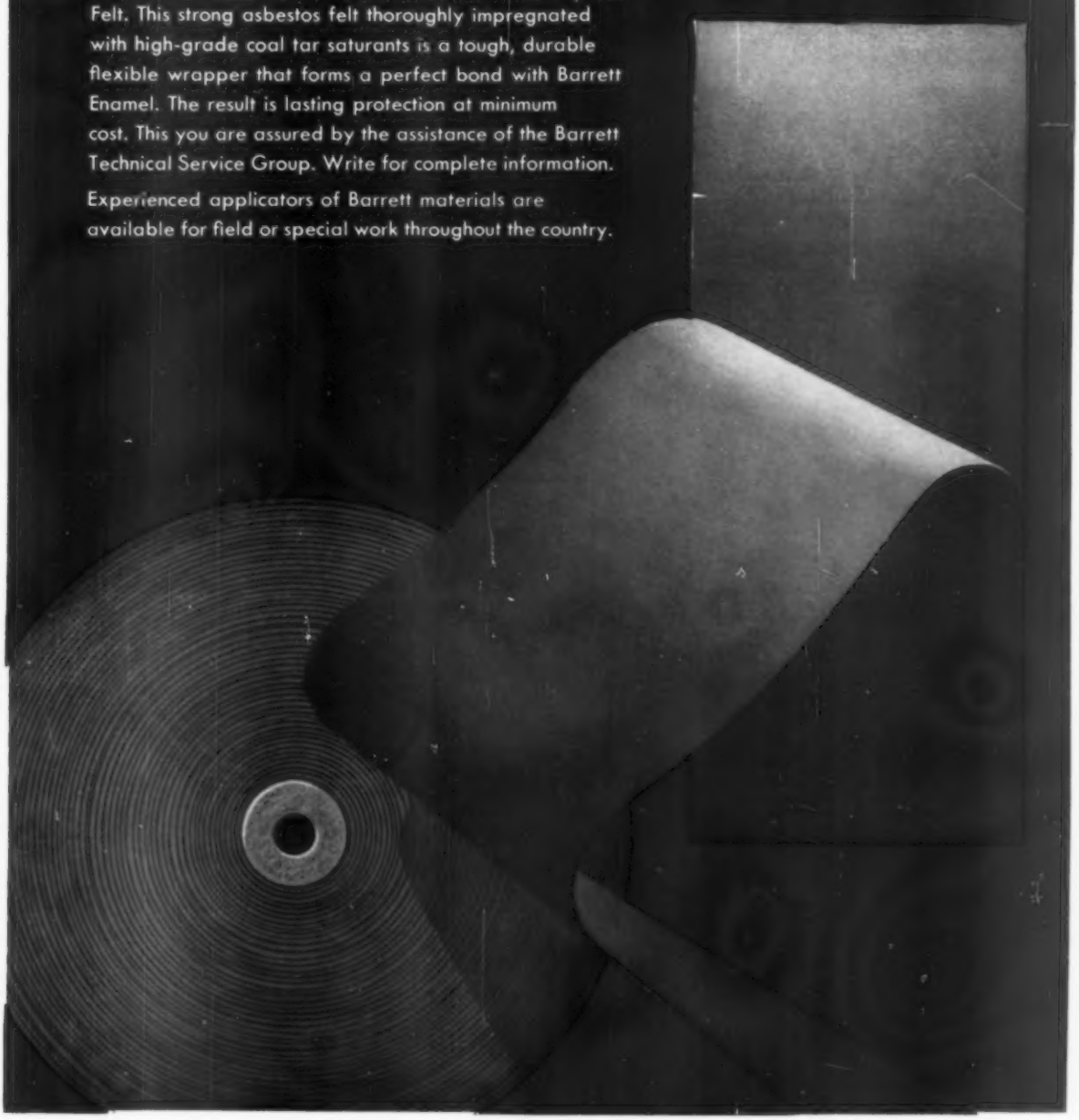
Ring Balance Recorders. Bulletin No. MSP-141, published by Hagan Chemicals & Controls, describes the company's newly designed line of Ring Balance recorders, indicators and controllers. The bulletin uses arrow and caption treatment to explain the many proprietary features incorporated in the instruments which have built their reputation for precise measurement and control of process variables. Also of help to engineers, is a full-page table of applications to show some of the many situations in which the Ring Balance principle gives outstanding performance. *Hagan Chemicals & Controls, Inc.*

Circle number (76) on reply card.

ALL-AROUND PROTECTION

You get all-around pipe protection with Barrett Pipeline Felt. This strong asbestos felt thoroughly impregnated with high-grade coal tar saturants is a tough, durable flexible wrapper that forms a perfect bond with Barrett Enamel. The result is lasting protection at minimum cost. This you are assured by the assistance of the Barrett Technical Service Group. Write for complete information.

Experienced applicators of Barrett materials are available for field or special work throughout the country.



Barrett

PROTECTIVE COATINGS

BARRETT DIVISION, Allied Chemical & Dye Corporation, 40 Rector St., N. Y. 6, N. Y. In Canada: The Barrett Company, Ltd., 5551 St. Hubert Street, Montreal, Que.

Allied Chemical

OVER 100 YEARS OF EXPERIENCE

ROLL UP PRODUCTION *with help like this . . .*

- EXCLUSIVE "ROLL-AWAY" MOLDBOARD . . . moves tough dirt fast
- NEW TOGGLE-TYPE CONTROL . . . kick-free in the rough . . . pinpoint accuracy
- HIGHEST AXLE AND THROAT CLEARANCE in its class . . . for better handling of biggest loads
- TOUGH TUBULAR FRAME . . . shock-absorbing strength down the middle
- BOX-SEAT COMFORT AND VISIBILITY . . . satisfied operators . . . more and better work done on all grading jobs

ROLL-AWAY is an Allis-Chalmers trademark

These are five of many reasons why Allis-Chalmers FORTY FIVE motor graders are showing up in more and more pipeline operations. They are precisely what the dirt-moving specialists ordered . . . ready now to handle right-of-way leveling and finishing easily, smoothly. Allis-Chalmers, Construction Machinery Division, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

Engineering in Action

PIPELINE DEVELOPMENTS ★ ★ ★

Roundup of Planned and Proposed Construction

The following tables list the company, mileage, pipe size, and location of proposed pipeline projects — crude, products, and natural gas —reported to *The Pipeline Engineer*. Company addresses are given when known.

CRUDE LINES

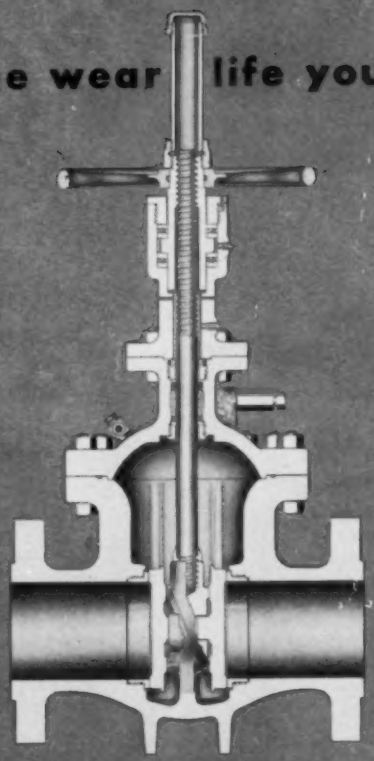
Name of Company	Miles	Size	Location
Act Oils, Toronto, Ontario	350	—	Line from Peace River area in British Columbia, thru Pine Pass to Prince George, westward to Bella Coola terminus on Pacific Coast
Atlantic-Cities-Service-Continental-Gulf-Phillips-Texas-Sinclair	Approx 385	26	Midland, Texas, area to Houston
Cape Pipe Line Company Philadelphia, Pennsylvania	200	—	Large diameter from Delaware Bay to Greater Philadelphia area refineries
Lakehead Pipe Line Company, Inc. Toronto 1, Ontario, Canada	80	26	Loop from Clearbrook, Minnesota, to Superior, Wisconsin
North-West Oil Pipelines Company	210	—	Wilhelmshaven, on the North Sea, to industrial Ruhr area of West Germany
Northwest Pipe Line Corporation Salt Lake City, Utah	350	8–10	Four Corners area to Salt Lake City, Utah
Offshore Gathering Company Houston, Texas	364	20	Gulf of Mexico from Sabine Pass to Mississippi River
Oil Field Pipe Line, Inc. Wichita, Kansas	—	8	To extend northeast from Hugoton field, Kansas, to Raymond, Kansas tie-in with Arapahoe Pipe Line system
Royal Dutch Shell Group and Others The Hague, Netherlands	870	30	Marseille, France, to Rotterdam, Holland, and Antwerp, Belgium
Royal Pipe Lines, Ltd. Regina, Saskatchewan, Canada	288	Var.	Cantuar area fields to Glenavon
Salt Lake Pipe Line Company Salt Lake City, Utah	100	10	Additions to Rangely, Colorado-Salt Lake City line
Seventeen American, British, French and Dutch companies	—	38–40	Likely route to run from head of Persian Gulf, through Iraq and Turkey to Turkish coast on the Mediterranean Sea
Sinclair Pipe Line Company Independence, Kansas	150	20	Teague to Houston, Texas
Southern Kansas Pipe Line Company	310	6, 10	10,000 bbl per day line from Greenwood pool, near Colorado line, thru Liberal to Arkansas City, Kansas
Texas-New Mexico Pipe Line Company Houston, Texas	515	16	Extension from Jal, New Mexico, pump station to Four Corners area
Trans-Border Pipe Line Company	110	—	Skagway, Alaska, to Whitehorse, Yukon Territory

PRODUCTS LINES

Name of Company	Miles	Size	Location
Buckeye Pipe Line Company	70	8	Wayne to Durand, Michigan, common carrier
Equitable Gas Company and Subsidiaries Pittsburgh, Pennsylvania	100	4–5	Maytown, Kentucky, to Institute, West Virginia
Laurel Pipe Line Company Pittsburgh, Pennsylvania	440	14–24	Philadelphia to Pittsburgh to Cleveland
Northwest Pipeline Corporation Salt Lake City, Utah	350	8–10	Four Corners to Salt Lake City, Utah
Ohio Oil Company	—	—	Common carrier line from Wood River, Illinois, to Chicago
Findlay, Ohio	—	—	Connecting line from Robinson, Illinois, refinery to new line
Salt Lake Pipe Line Company Salt Lake City, Utah	80	8	Additions to Boise, Idaho, to Pasco, Washington, line
Service-Continental-Sinclair-Phillips	550	—	Salt Lake City, Utah, to Spokane, Washington
Union Oil Company of California	815	—	Shale Oil Plant, Rifle, Colorado, to Los Angeles area
Winnipeg & Central Gas Company Winnipeg, Manitoba, Canada	210	6	U. S. Canadian border to Winnipeg

New CRANE Double-Disc Valve

has the wear life you want on pipeline service



ORDER NOW!

Available in sizes 4 to 24 inches; flanged ends (No. 1680) or butt-welding ends (No. 1681). Either spur or bevel gearing can be provided. For full details, see your local Crane Representative or write to address below.

Developed for both oil and gas transmission, this new Crane gate valve has the long-wear features you want for steady, trouble-free service in your lines.

This new Crane valve design has free-to-rotate double discs—hung independently to change seating position with every operation. Each time this valve is opened or closed, both discs are free to turn to provide cleaning action on seating contact areas, and thus prevent abrasive materials from collecting.

Disc clearances are always accurate, because the two identical discs move up and down in machined body-guide ribs—which take the service abuse usually forced on disc faces in conventional double-disc gate valves, a frequent cause of damage and costly maintenance.

Consider and compare, too, the perfect disc alignment in this smooth-working Crane pipeline valve. Annular-shaped machined wedging surfaces keep both discs and the body ring seat faces lined up at all times—and, in addition, compensate for any slight body deflections caused by line strains.

CRANE VALVES & FITTINGS

PIPE • KITCHENS • PLUMBING • HEATING

Since 1855—Crane Co., General Offices: Chicago 5, Ill.—Branches & Wholesalers Serving All Areas

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

for cooling tower application...

There's MORE protection against humidity in Allis-Chalmers MOTORS

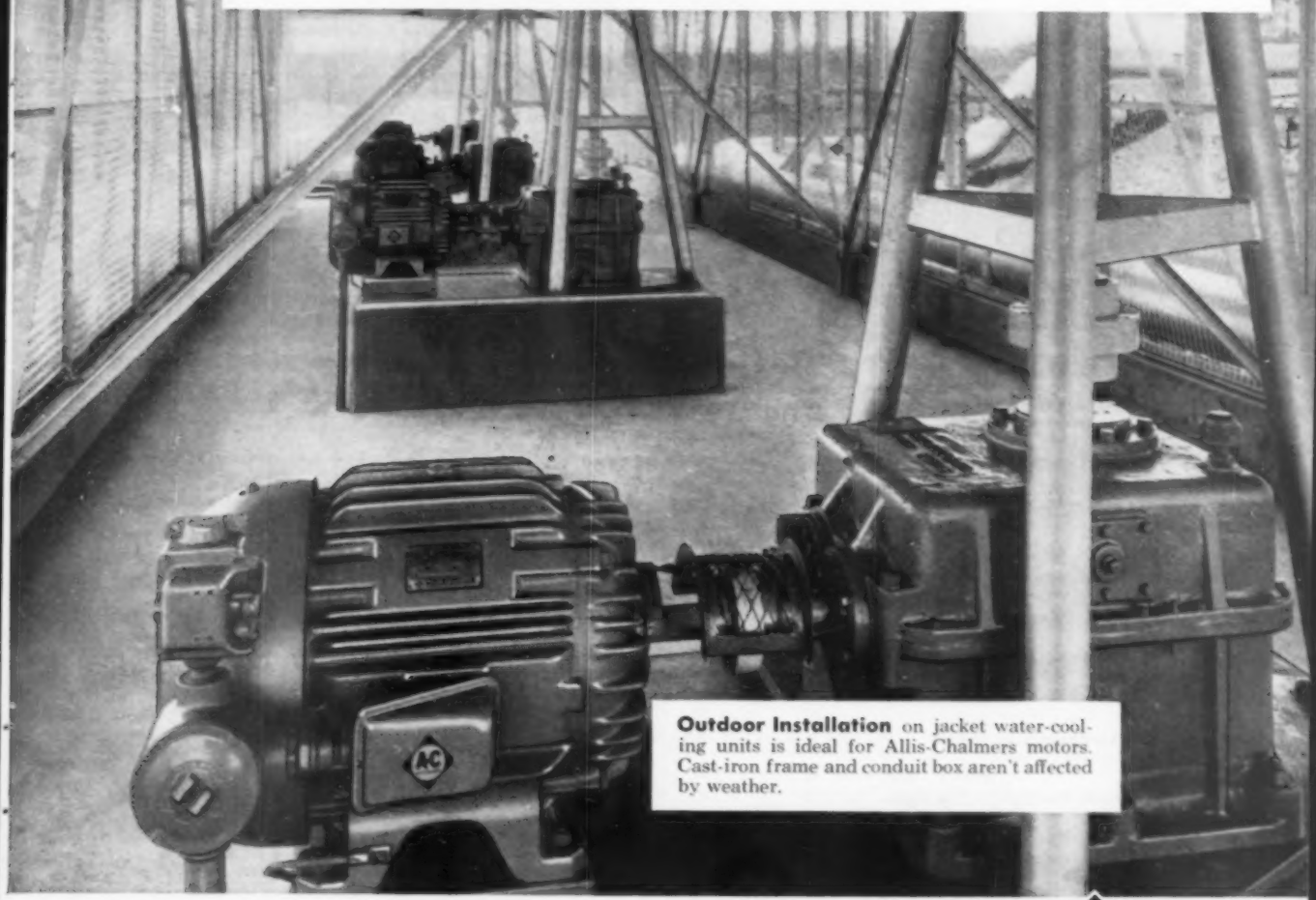
The ultimate in protection against high humidity — major cause of cooling tower motor failure — is provided tower builders and users in Allis-Chalmers TEFC motors. Here's why:

1. **Moisture drainage** — Drain plug can be removed to eliminate condensed moisture in the motor. (Particularly helpful in intermittent operations where condensation is more likely.)

2. **Extra-insulated stator** — Several applications of special insulating varnish plus repeated baking keep humidity out . . . give the long electrical life you need.

3. **Weather-protected bearings** — Rotating seal, turning in close running clearances, guards against entry of water.

Find out more about the "MORE" in Allis-Chalmers motors by contacting your nearby A-C sales office or distributor, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wis.



Outdoor Installation on jacket water-cooling units is ideal for Allis-Chalmers motors. Cast-iron frame and conduit box aren't affected by weather.

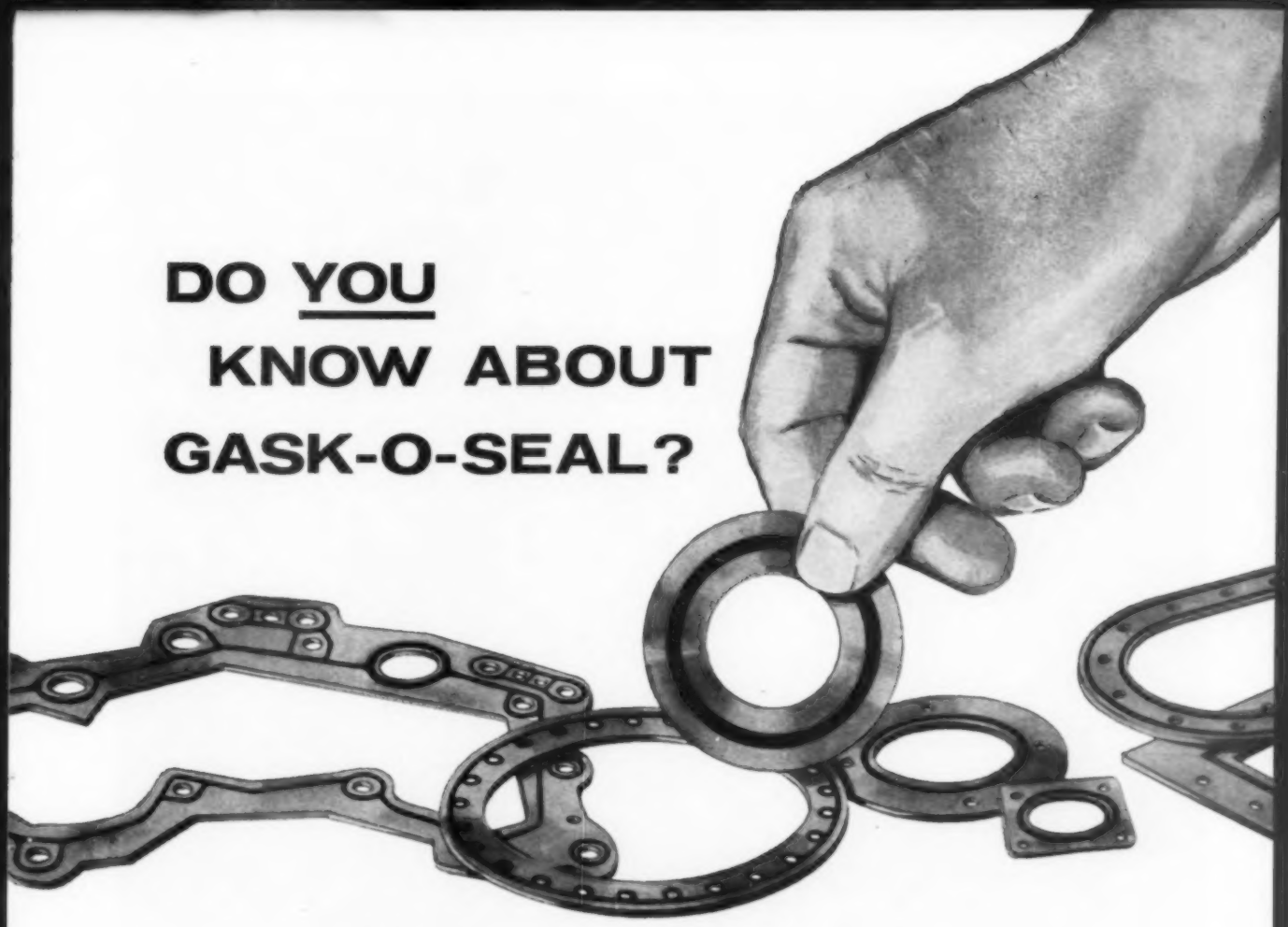
ALLIS-CHALMERS

A-5183

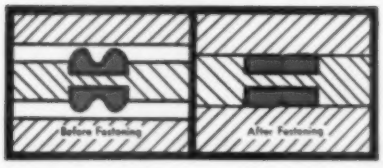
GAS LINES

Name of Company	Miles	Size	Location
Andes Pipeline Corporation	500	12	Villamontes, Bolivia, to Antofagasta, Chile
Arkansas Louisiana Gas Company	300	—	Main and gathering lines Louisiana-Texas Gulf Coast
Cities Service Oil Company Bartlesville, Oklahoma	70	—	Gas gathering system on the Roberts Ranch, Midland, Texas
Coastal Transmission Corporation	574	22–26	McAllen, Texas, to Baton Rouge, Louisiana
Dallas, Texas	414	Var.	Gathering lines in Rio Grande Valley, Texas
Colorado Interstate Gas Company	345	30	Kit Carson, Colorado, to Beatrice, Nebraska
Colorado Springs, Colorado	100	24	Springfield to Pueblo, Colorado
	24	24	Greenwood to Panhandle-Kit Carson loop
	109	26	Loop from Fourway, Texas, to Springfield, Colorado
	66	30	Loop from Springfield to Kit Carson, Colorado
	10	16	Keyes field, Oklahoma, to mainline
	6	10	Tablerock field, Wyoming, to mainline
	12.0	12–24	Additions in Texas Panhandle fields
	50	22	Mocane field, to Hooker, Oklahoma
Eastern Shore Natural Gas Company Salisbury, Maryland	124	6, 8	Transmission line and facilities in Delaware and Maryland
El Paso Natural Gas Company El Paso, Texas	500	30	Twin Falls, Idaho to California state line near Las Vegas
Kansas-Nebraska Natural Gas Company	61.3	Var.	Gathering lines from Camerick field to Liberal, Kansas
Phillipsburg, Kansas	10	10	Grand Island to Fullerton, Nebraska
	10	8	Loop from Grand Island to Fullerton, Nebraska
	11.5	12	Replacement from Scott City to Oakley, Kansas
	1.2	6	Additions to system in Nebraska
	9	8	Lexington to Central Nebraska Public Power Electric Plant
	14	16	Replacement from North Platte to Maxwell, Nebraska
Midwestern Gas Transmission Company	1112	12–24	Mainline from U. S. Canadian border near Emerson, Manitoba — Noyes, Minnesota, to Portland, Tennessee
	648	3–18	Laterals of mainline to serve communities in Minnesota, North Dakota, and Wisconsin
Mississippi River Fuel Corporation St. Louis, Missouri	54	26	Parallel sections to existing system
Natural Gas Pipe Line Company of America	38	36	Joliet to Elgin, Illinois
Chicago, Illinois	405	36	Beaver County, Oklahoma, to Joliet, Illinois (loops)
	25	—	Gathering line from Quinduna field, Roberts County, Texas, to point on existing line
	91	30	Loops in Nebraska, Kansas, Oklahoma
	337	30	Looping between Texas terminus and Beatrice, Nebraska
Northern Natural Gas Company	28	24	Ogden to Redfield storage area, Iowa
Omaha, Nebraska	168	20	St. Paul-Minnesota to Duluth, Minnesota, and Superior, Wisconsin
	100	20–24	Savannah Creek field, Alberta, to Alberta-Montana border near Cardston, Alberta
Northern Plains Natural Gas Company (subsidiary of Northern Natural Gas Company) Omaha, Nebraska	1100	26	Alberta-Montana border to Minneapolis, Minnesota
Offshore Gathering Company Houston, Texas	364	30	Offshore gas line in Gulf of Mexico from Sabine Pass to Mississippi River
Ohio Fuel Gas Company Columbus, Ohio	37.7	24	Parallel line from Crawford station, to station in Licking County, Ohio
	17.2	20	Extend line from Jackson County terminus to station in Lawrence County, Ohio
Pacific Gas & Electric Company San Francisco, California	1300	—	Alberta, Canada, gas fields to Antioch, California
Permian Basin Pipeline Company Omaha, Nebraska	83	16	Interconnection from proposed Pioneer's gathering system to Permian's facilities at Spraberry, Texas
Tennessee Gas Transmission Company	264	26, 30	Loops in Tennessee, Kentucky, West Virginia and Pennsylvania
Houston, Texas	557	30	From existing facilities in Mississippi Delta south of New Orleans to Portland, Tennessee
	76	24	Coudersport, Pennsylvania, to Hamburg, New York
Texas Eastern Transmission Corporation	96.5	30	Additional looping on existing system between Kosciusko, Mississippi and Uniontown, Pennsylvania
Shreveport, Louisiana	40	Var.	New laterals on same line
Texas-Illinois Natural Gas Pipeline Company Chicago, Illinois	59	20	Joliet to Volo, Illinois
Transcontinental Gas Pipe Line Corporation	13	24	Purchase lateral in Louisiana
Houston, Texas	247	12–24	Purchase laterals in Texas
	57	36, 30	Mainline loops in Louisiana, Mississippi, Alabama, Georgia, and South Carolina
Trans-Western Pipe Line Company Los Angeles, California	—	—	Four Corners area to point in California
Westcoast Transmission Company, Ltd.	174	30	Line from Savannah Creek gas field, Alberta, to existing system

DO YOU KNOW ABOUT GASK-O-SEAL?



The static seal that can not blow out!



The above diagram is "typical" only. Gask-O-Seals are also made with one-side seals.

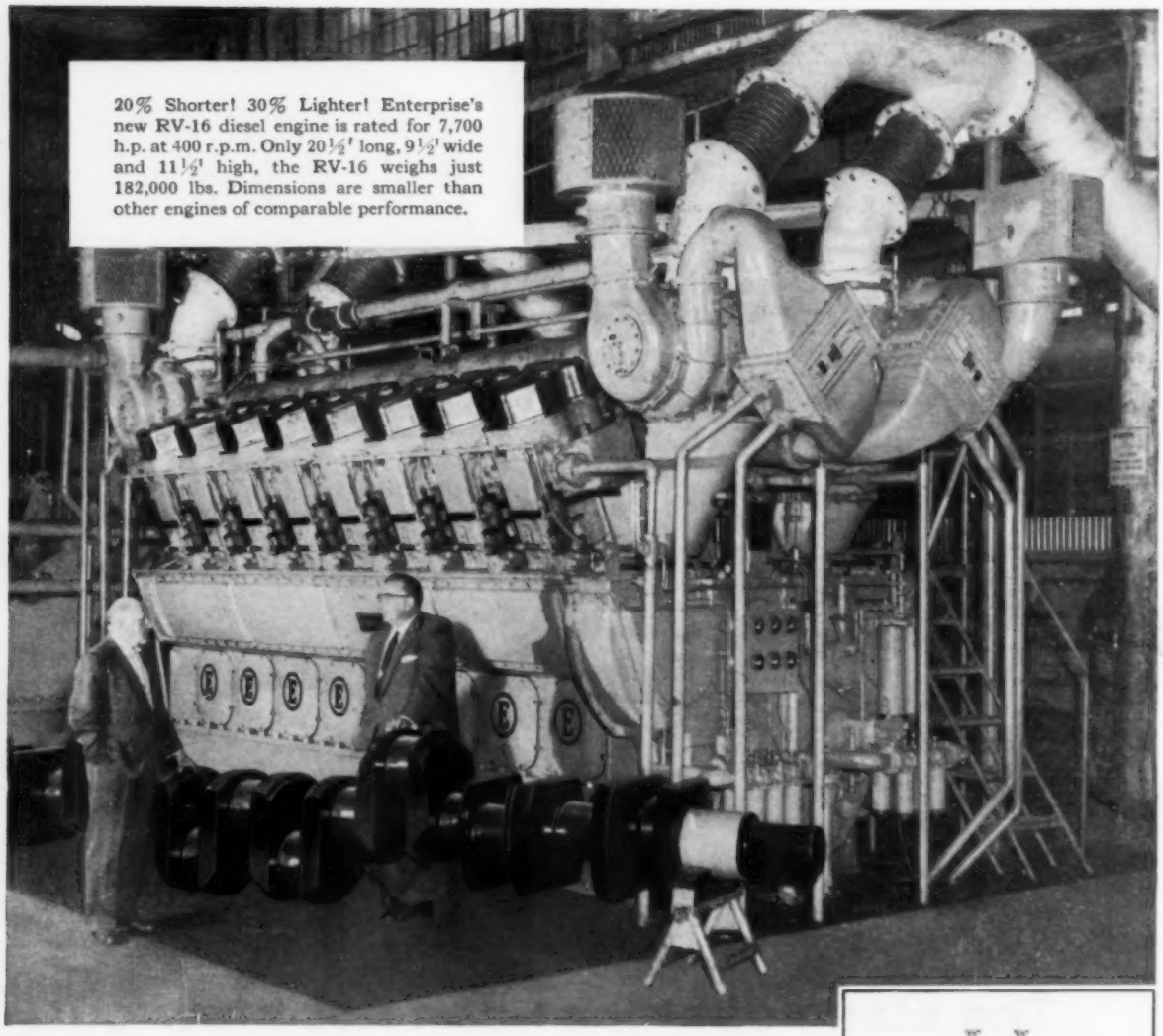
If you do not know about Gask-O-Seals look at these facts:

- ✓ Gask-O-Seals will seal practically any processable fluid . . .
- ✓ Gask-O-Seals can be re-used . . .
- ✓ Gask-O-Seals will seal at low or high pressures, vacuum or positive . . .
- ✓ Gask-O-Seals are available as standards and as specials in almost any configuration or to meet special requirements.

They are recommended for flanges, gear boxes, transfer cases . . . *any* place where truly efficient static seals are needed.

Note: A recent development of the Gask-O-Seal principle indicates effective sealing in the temperature ranges of −400° to +1000° for specific applications.

FRANKLIN C. WOLFE CO.
Culver City, California
"sealing design specialists"
A DIVISION OF Parker APPLIANCE COMPANY
Hydraulic and fluid system components



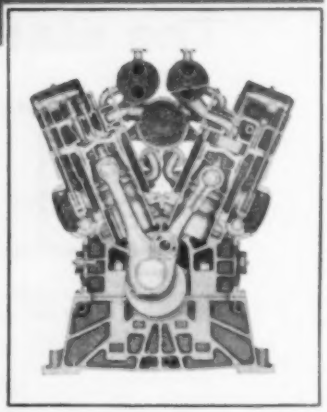
20% Shorter! 30% Lighter! Enterprise's new RV-16 diesel engine is rated for 7,700 h.p. at 400 r.p.m. Only 20½' long, 9½' wide and 11½' high, the RV-16 weighs just 182,000 lbs. Dimensions are smaller than other engines of comparable performance.

Enterprise Chooses KOPPERS Piston Rings Exclusively for RV-16

Prototype of a new line of industrial diesel engines, the RV-16, built by Enterprise Engine & Machinery Co., of San Francisco, is designed for such rugged operations as delivering main propulsion in towboats and seagoing freighters, or supplying power for pumping stations or electric generation.

As many other leading manufacturers have done, Enterprise has selected Koppers Piston Rings exclusively. Koppers wide range of types and sizes . . . variety of material selection . . . control of material quality . . . close tolerance performance . . . rigid standards of inspection—all contribute to Koppers leadership in the field of industrial piston and sealing rings, making Koppers the most dependable source of supply.

If you have a problem of ring application, avoid further needless expense. Take advantage of Koppers experience, research facilities and craftsmanship. Write for information today. KOPPERS COMPANY, INC., Piston Ring and Seal Department, 1709 Hamburg Street, Baltimore 3, Maryland.



Cutaway shows internal design of the RV-16

KOPPERS

AMERICAN HAMMERED
Industrial Piston Rings
Engineered Products Sold with **Service**

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

Plantation's new 18" pipeline carries gasolines, kerosenes, diesel and fuel oils 327 miles from Baton Rouge, La., to Helena, Ala.

Blue Flag helps protect Plantation's new 18" pipeline against corrosion

By using glass fiber mat to reinforce the enamel coating, Plantation Pipe Line Co. helped give longer lasting protection against corrosion to its new line, tapping the Gulf Coast for southeastern markets. Blue Flag Pipe Wrap was used on approximately 100 miles of this project.

L·O·F Glass Fibers' Blue Flag guards pipelines against corrosion by strengthening protective enamel, and increasing its resistance to soil stress and backfill damage. Its uniform porosity allows enamel to bleed through quickly, lets trapped gas escape easily. Result: far fewer "holidays" and greatly increased pipeline service life. Cost: less than ½ of 1% of initial investment.

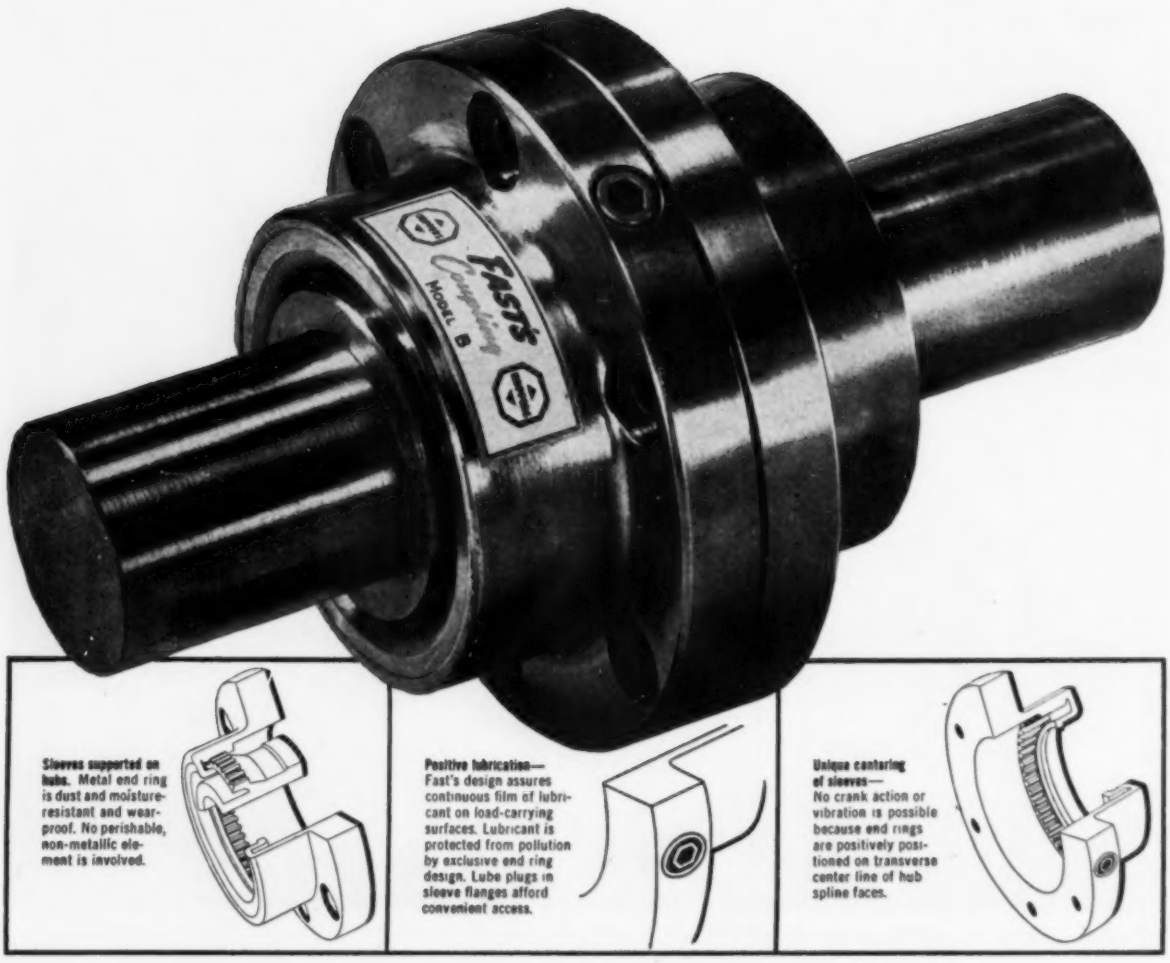
Blue Flag Pipe Wrap is made from inert glass fibers which resist the action of soil chemicals. And its high tensile strength virtually eliminates breakage in the field and resulting time loss.

For long-lasting pipeline protection at low cost, insist on Blue Flag reinforcing inner-wrap for your over-the-ditch and yard-wrapped pipe. Your nearest distributor gives fast delivery. For his name, or for full technical information, write today: *L·O·F Glass Fibers Company, Dept. 72-97, 1810 Madison Ave., Toledo 1, Ohio.*

L·O·F GLASS FIBERS

L·O·F GLASS FIBERS COMPANY · TOLEDO 1, OHIO

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD


FAST'S
Coupling
MODEL B
Sleeves supported on hubs. Metal end ring is dust and moisture-resistant and wear-proof. No perishable, non-metallic element is involved.
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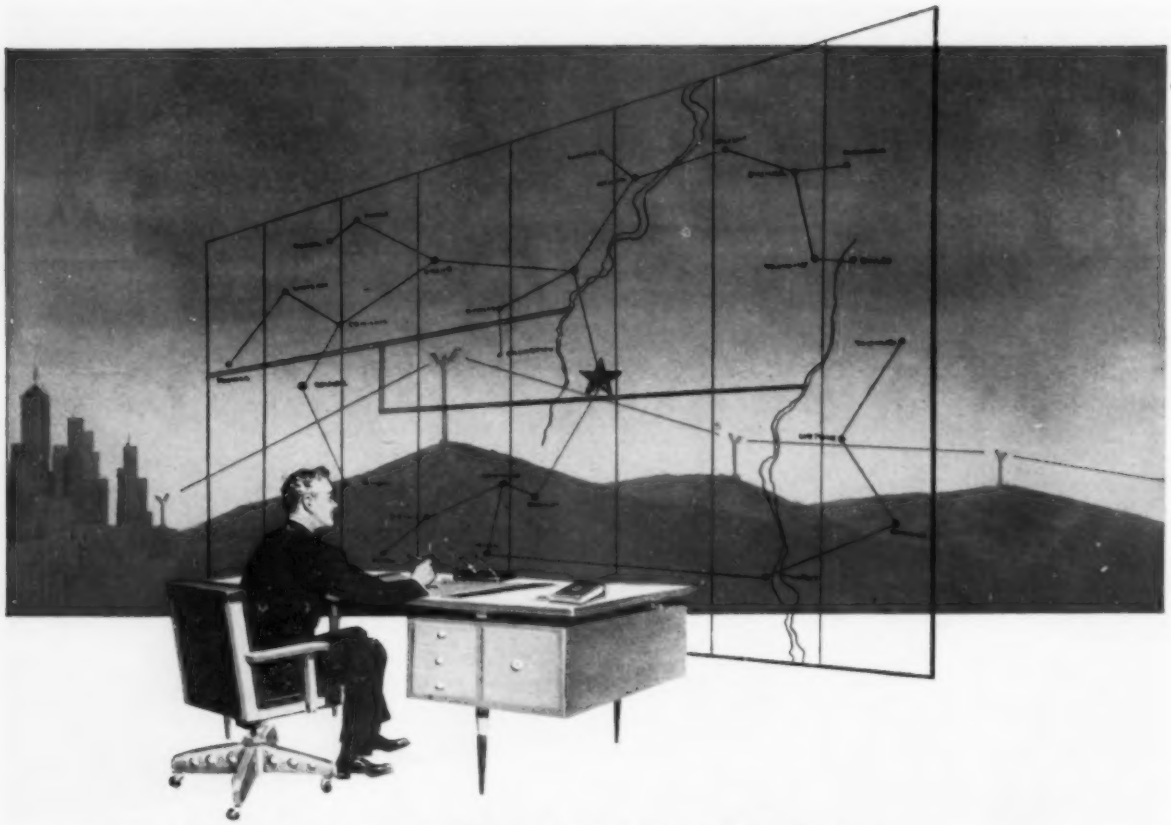

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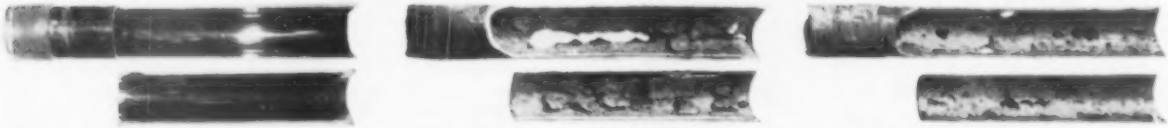

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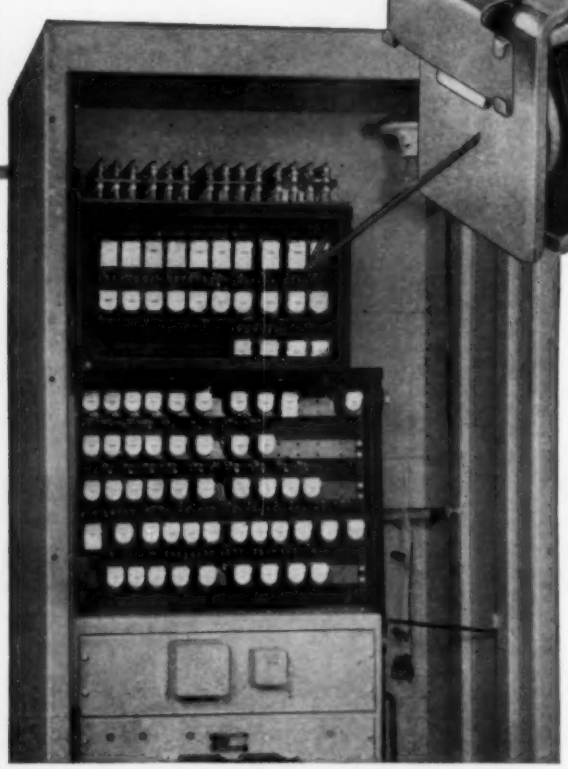

UNION Centralized Transport Control Equipment for the central office (back view) uses plug-connected units for ease of handling.

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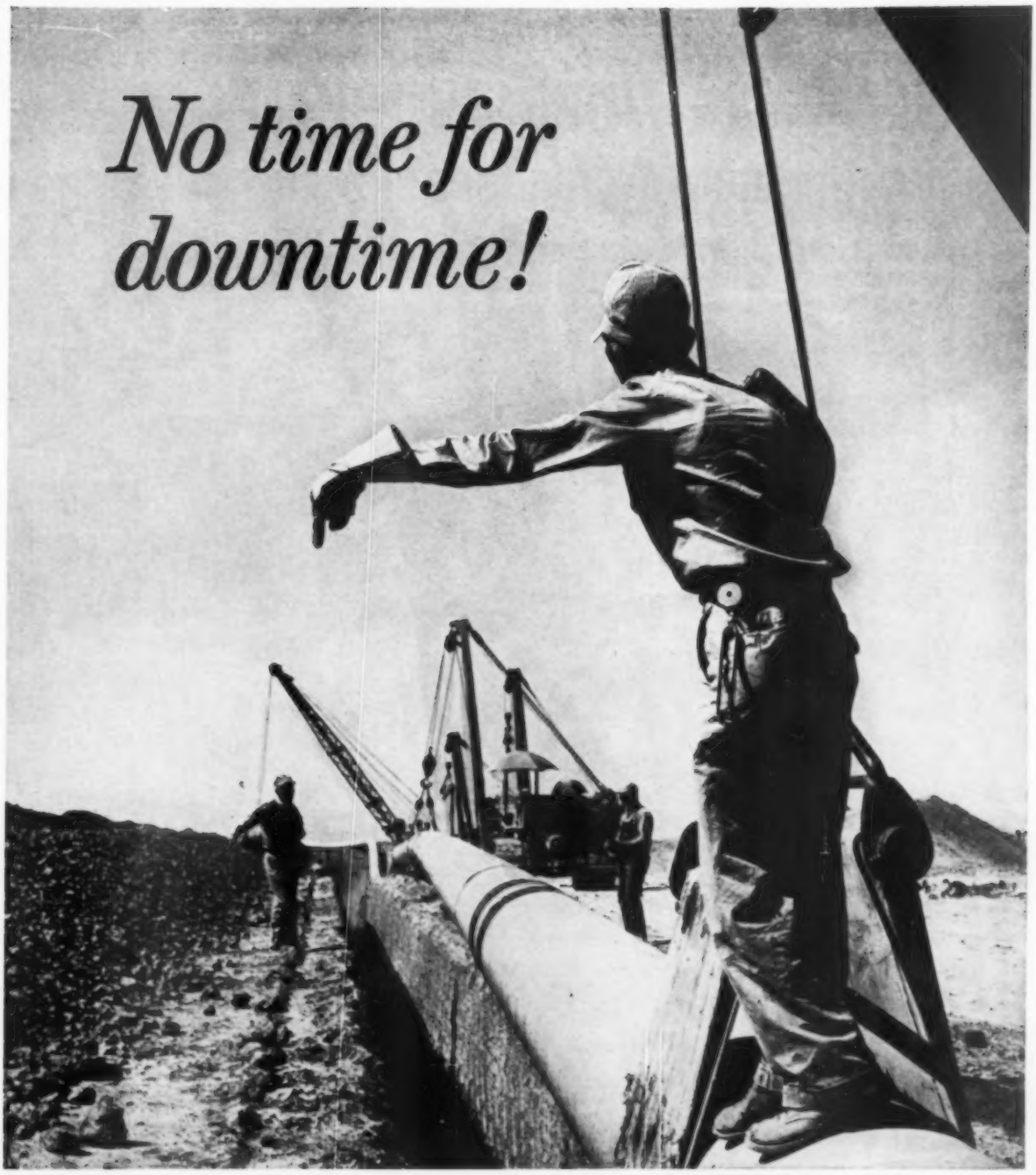

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makes this a model pipe wrapping plant

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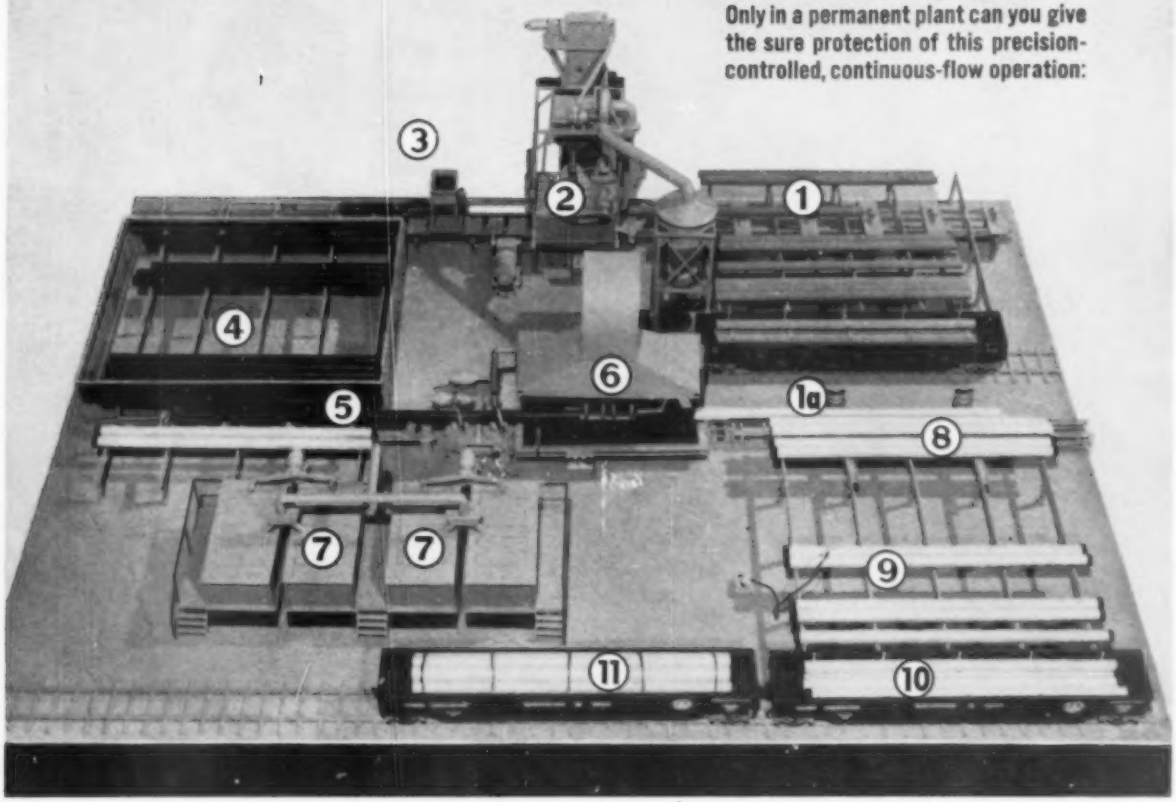

1. Caustically-cleaned pipe enters plant from yard.

1a. Bare pipe is unloaded direct from car in plant.

2. Roto-grit blaster removes all trace of rust, mill scale.

3. Machine applies primer.

4. Primer cures in heat room.

5. Automatic conveyor delivers pipe to—

6. Coating and wrapping machine.

7. Automatic kettles flow enamels to coating and wrapping machine.

8. Coated and wrapped pipe is delivered to an electronic-inspection area.

9. Holiday detector inspection area.

10. Pipe is loaded on flat car, according to specification MD-4, developed by Hill, Hubbell and given to the Association of American Railroads.

11. Permanently protected pipe awaits delivery to the job.

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At the dispatching center of Shell's products pipeline general field office, Indianapolis, scheduler Robert Formby collects data from remote pumping stations.

Teletypewriters give Shell dispatcher immediate readings from four remote pumping stations

"New Douglas station suction 60 pounds, discharge 600 pounds, motor load 100 amps . . ." that's what the teletypewriters above tell Shell Oil Company's Indianapolis dispatcher about operations at an unattended pumping station over 200 miles away.

Bell System private line teletypewriters connect the dispatcher with four remote stations on Shell's "east line," which carries 33,000 barrels a day from the Wood River, Ill., refinery to Illinois, Indiana and Ohio markets.

The dispatcher simply pushes the proper buttons and the distant station is instantly on the circuit. Data on the remote operation is then received on his teletypewriter. By pushing other buttons, he can also start and stop pumps at the locations.

* * * *

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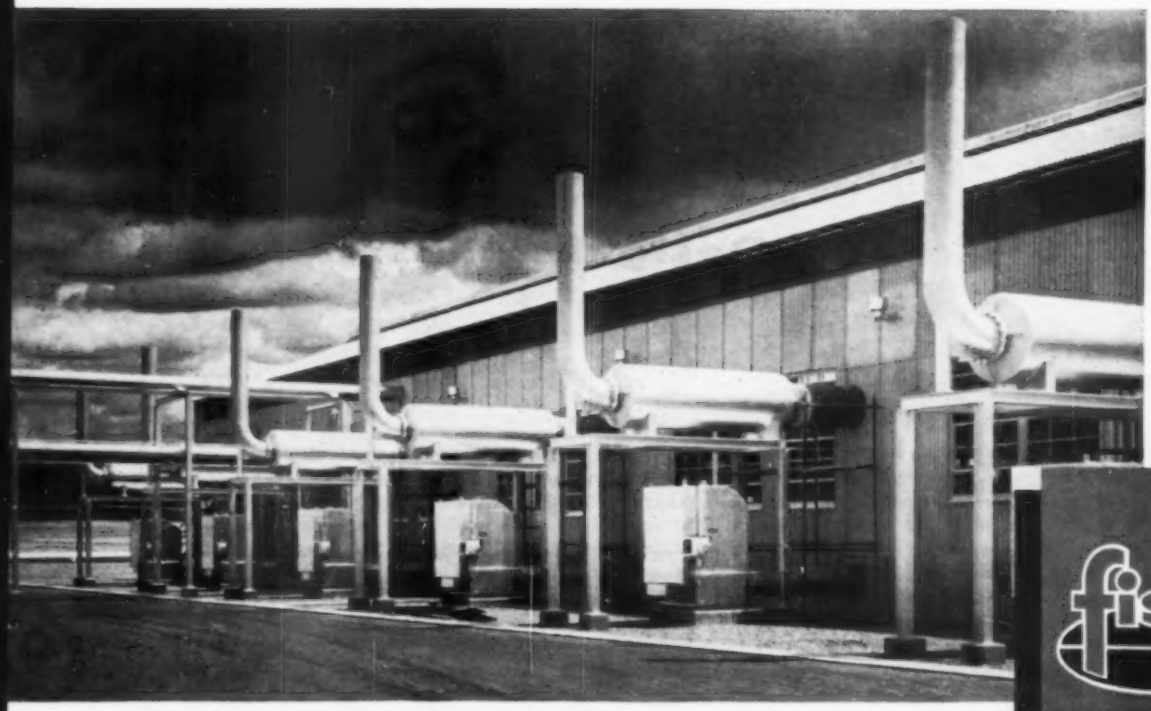
why this key compressor station works dependably despite these

temperature extremes



Compressor Station One is the key supply installation on the sprawling Pacific Northwest Pipeline system. Located at 6000 feet elevation near Ignacio, Colorado, the facilities boost pressure of nearly 300-million cubic feet of gas per day from the San Juan Basin gathering system. This station feeds a nearby gasoline plant before starting the gas on the long haul to the Pacific Northwest market.

In such a key spot, dependability is essential. Fish engineers carefully reviewed possible causes of trouble long before thoughts went into plans.

Extreme temperature fluctuations—from plus 100 degrees F. to minus 20 degrees F.—posed unusual problems. Under these conditions, reliable temperature control was difficult to achieve.

To be sure of providing efficient jacket water and lube oil temperatures under all extremes of ambient temperature and load, Fish designers elected to use unitized systems. Under this system, each engine has its own atmospheric cooler to take care of jacket water and lube oil cooling loads. A system of temperature control instruments was installed to provide very close control under all operating conditions. As designed, this remote station demonstrates extreme flexibility with reliability.

This is but one example of the type of advanced engineering you get from Fish. In addition, the same quality service prevails from feasibility study to project completion. If you are contemplating new or expanded facilities in oil, gas or chemicals, consult with Fish.

the fish companies
HOUSTON

FISH ENGINEERING CORPORATION
FISH NORTHWEST CONSTRUCTORS, INC.
FISH SERVICE CORPORATION

This article describes step-by-step how a computer is operated to solve engineering problems

Automation

Makes Gas System Designing Easier

S. Ochi
Bendix Computer Division
Bendix Aviation Corporation

MODIFICATION of a typical pipeline system consisting of 300 sections requires computation of the same basic problems 300 times. Peak human efficiency for this type of mathematical labor is probably 15 minutes per section calculation. A selected design for this system may be said to be the result of 75 computation hours, if the statistical information for one plan only is used. A reliable, efficient decision must be based upon the evaluation of different parameters. Therefore, this entire procedure of manual computation has to be repeated each time new data are considered.

Development and planning that involve repetitive solutions to the same basic problems constitute one of the easiest and most rewarding types of industrial situations being resolved by the application of electronic computers. Once a program is prepared, containing instructions to the computer for executing the desired arithmetic and input-output operations, it can be used an infinite number of times by simply inserting the pertinent data. Further, to fit related problems, modifications of a program may be made with comparable ease.

Effectiveness of the Bendix G-15D when applied to repetitive-type problems is shown in the following example. For illustrative purposes this example is only a small fragment (13 sections) of an actual gas pipeline system of several hundred sections.

These figures mean more than easily stated time-cost savings. They mean:

1. **It is practical and possible to base decisions upon a thorough analysis of the factors involved, substantiated by complete and accurate data.**
2. **Answers are readily available at the time when most needed.**
3. **Valuable manpower is released for more productive work.**

These intangible benefits are among the most valuable contributions of electronic computers to industry.

The example shown here utilizes routines that can be adapted readily to a more complete design problem. Varying combinations of increased compressor capacity or additional pipes in parallel can be considered as a basis for reaching a decision on the efficiency of proposed systems. This problem is intended to describe the general methods and results to be found in many G-15D applications.

As this example typifies the types of calculations repeatedly executed in a pipeline design problem, the coding was accomplished in straight machine language. Coding techniques aimed at reduction in memory space and computing time were utilized. Problems of a more restricted nature can be coded using Intercom Coding. The Intercom Code is a coding system on the G-15D that permits problems to be easily coded. A saving of programming time results. This method is not as fast in computation time and requires more memory space.

Problem:

To determine the pressure necessary at the source in order to deliver gas to a destination in certain quantities at a given pressure.

Gas is delivered through pipelines varying in number, diameter, and physical condition. For some sections the pipeline consists of two pipe in parallel, whereas in other sections there are three. The problem has been programmed for calculations on sections having as many as six lines in parallel.

Compressor stations are included at points in the system to boost the pressure, especially where large changes in elevation are involved. Quantity of gas in the line may be varied by feeder lines that can add gas to the line or take it away to other points. For the purpose of calculations, the system has been broken into pipeline sections, each identified by a mile post designation.

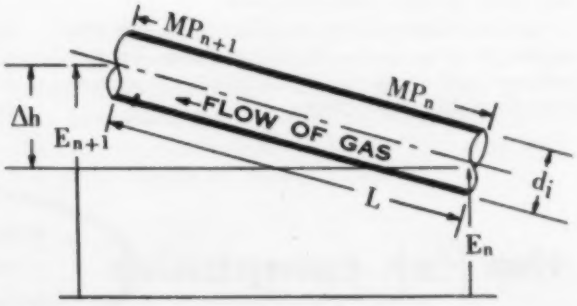


FIG. 1. Pipe section.

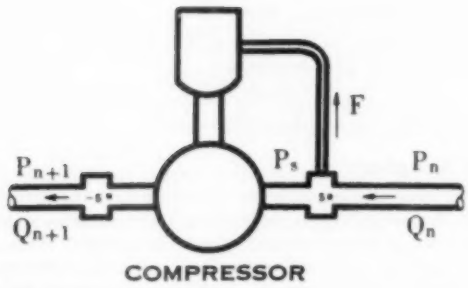


FIG. 2. Compressor section.

The end of a pipeline section is determined by a change in one of the following factors:

Change in the sign of Δh (elevation correction),
Branch points (feeder lines),
Change in the number of parallel pipes,
Change in the diameter of pipes,
Variations in pipe condition,
Insertion of compressor station.

Although this particular problem is a special one due to the extreme elevation changes involved, it is illustrative of the basic methods that are used in solving gas pipeline problems on the computer.

Formulae Involved:

There are three basic formulae involved in this problem. The first is that for calculating the flow of gas in a pipe; the second, calculating brake horsepower for a reciprocating compressor station; the third, calculating brake horsepower for a centrifugal compressor station.

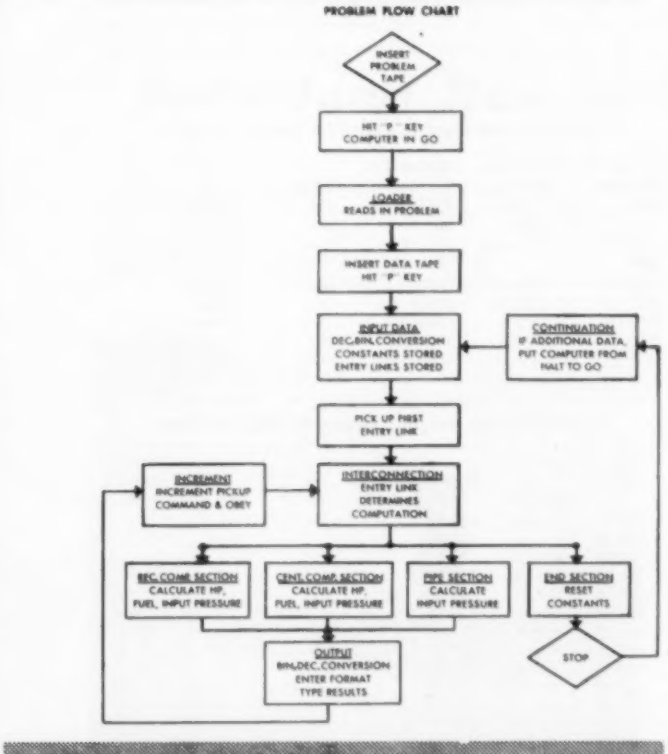

PROBLEM FLOW CHART
INSERT PROBLEM TAPE
HIT 'P' KEY COMPUTER IN GO
LOADER READS IN PROBLEM
INSERT DATA TAPE HIT 'P' KEY
INPUT DATA DEC.BIN.CONVERSION CONSTANTS STORED ENTRY LINES STORED
CONTINUATION IF ADDITIONAL DATA, PUT COMPUTER FROM HALT TO GO
PICK UP FIRST ENTRY LINE
INCREMENT INCREMENT PICKUP COMMAND & OBEY
INTERCONNECTION ENTRY LINK DETERMINES COMPUTATION
REC.COMP.SECTION CALCULATE HP, FUEL, INPUT PRESSURE
CENT.COMP.SECTION CALCULATE HP, FUEL, INPUT PRESSURE
PIPE SECTION CALCULATE INPUT PRESSURE
END SECTION RESET CONSTANTS
STOP
OUTPUT BIN.DEC.CONVERSION ENTER FORMAT TYPE RESULTS

FIG. 3. Problem flow chart.

Glossary of Symbols

"E" = efficiency or judgment factor, assumed .92 for new, clean pipe
P = pressure of pipeline in psia
Q = flow rate of gas in M³CF
L = length of pipe section in miles
MP_n = mile post (increasing in direction of flow) in miles
E_n = altitude of mile post in feet
d_i = inside diameter of pipe in inches
P_b = pressure base in psia
G = specific gravity of gas (relative to air)
T = flow temperature in degrees absolute (F + 460)
M³CF = million cubic feet per day
r = compression ratio
F = fuel used by compressor in M³CF
BHP = brake horsepower
SLHP = sea level horsepower
E.C. = elevation correction
P_s = suction pressure in psia
m = specific heat ratio
Z = compressibility factor

Most engineers are familiar with the standard energy equation methods from which the differential equation for the flow of gas in a pipe can be derived. When elevation changes are disregarded and certain variables assumed constant, an analytical solution can be obtained based upon these methods. In most cases, however, a greater degree of accuracy is required, and for this purpose the Panhandle Eastern Flow Equation was developed. Due to the significant elevation changes in the example shown here, it was necessary to derive a modified form of this equation.

Modifications to the Panhandle Eastern Flow Equation vary from company to company. The exact equation used is often determined by company policy. Corrections for static head can be made from either the higher or lower end of a pipe section.

The particular form of the Panhandle Eastern Flow Equation used is:

$$P_{n+1} = \frac{1}{1-c}\left\{(P_n^2 + D \cdot \alpha)^{0.5} + c \cdot P_n\right\}$$

Where:

$$\alpha = \frac{1-c}{1+c} \qquad \text{if } \Delta h < 0$$

$$= 1 \qquad \text{if } \Delta h \geq 0$$

$$c = 0.5\,(2.53 \cdot 10^{-5})\,\Delta h$$

$$D = \left(\frac{Q}{K}\right)^{1.8539} \cdot L$$

$$L = MP_n - MP_{n+1}$$

$$\Delta h = E_n - E_{n+1}$$

$$K = .000889 \cdot \frac{14.73}{P_b} \cdot \left(\frac{312}{G \cdot T}\right)^{.5} \cdot \text{"E"} \cdot \sum_{i=1}^{m} d_i^{2.6182}$$

FIG. 4. Operator holding a paper tape magazine, removed from the high speed photoelectric reader on the front of the computer.

The static head correction is made at the lower end of the pipe section, after which frictional losses in pressure are determined. The value of Δh is determined and used in the formulation of the quantity α. The form of α is seen as dependent upon whether the pipeline gains or loses elevation. The 1.8539 power of Q/K is computed using a subroutine for the generation of a fractional power of a number. The subroutine is based upon a Taylor's Series expansion. The square root of $(P_n^2 + D \cdot \alpha)$ is generated by a subroutine using an iteration procedure based upon Newton's method.

Calculations for the compressor stations have much in common, but the horsepower requirements are based upon a different presentation of the compressor characteristics. For the reciprocating compressor station, the following formula is used:

$$BHP/M^2CF = \left(\frac{P_b}{14.4}\right)\left(\frac{T}{520}\right)(c_o + c_1 r + c_2 r^2 + \cdots + c_6 r^6)$$

where the c constants are empirically determined. A subroutine generates this polynomial.

For the centrifugal compressor station, the comparable equation is:

$$BHP/M^2CF = 284.24\left(\frac{P_b}{14.9}\right)\left(\frac{540}{T}\right) Z\left(r^{\frac{m-1}{m}} - 1\right)$$

where the compressibility factor Z is given by

$$Z = 0.9975 - 0.00022P_s + 10^{-6} \cdot P_s(T - 460) - 5.10^{-5}(T - 460)$$

Total quantity of gas entering the compressor is

$$Q' = \frac{Q}{1 - 2.82 \cdot 10^{-4}\, BHP/M^2CF}$$

From this, the fuel consumed in compressing the gas is given by

$$F = Q' - Q$$

The brake horsepower is given by

$$BHP = BHP/M^2CF \cdot Q'$$

and the sea level horsepower by

$$SLHP = BHP \div E.C.$$

The elevation correction differs for the two compressors. For the reciprocating compressor, it is:

$$E.C. = 1.06198 - 4.3667 \cdot 10^{-5}E + 5.0932 \cdot 10^{-10}E^2$$

for elevations above 1500 ft, and unity for less than that.

For the centrifugal compressor, it is

$$E.C. = 1.03666 - 3.666 \cdot 10^{-5}E$$

for elevations greater than 1000 ft, and unity for less.

Data Supplied:

Data used in this problem is supplied from a knowledge of the characteristics of the proposed system as well as from the necessary requirements at the delivery point. This information is first recorded on punched paper tape through the use of a typewriter keyboard. In this example, the information is typed as shown in Table 1.

The first line of information deals with the constants that are used throughout the problem. It, along with the second line, represents the initial conditions to the problem. The section code is used to determine whether computations are for processing of initial condition data, a pipeline section, or compression station.

These codes are:

15 Pipe Section
20 Reciprocating Compressor
30 Centrifugal Compressor
80 Initial Conditions
85 End of Data

Whether the pipe code or compression ratio is being entered, is determined by the character of the section. As can be seen, zeros are entered for pipe sections with fewer than six pipes in parallel.

Computation

This particular problem has been planned so that any reasonable number of sections (up to several hundred) can be computed. Fig. 3 is a flow chart illustrating the main parts of the computer program.

A tape magazine with the problem tape is placed in position as shown in Fig. 4. The operator then hits the "p" key on the typewriter, which initiates reading of the tape by the

TABLE 1. Information Typed for Sample Problem.

Pressure Base	Specific Quantity of Gas	Temperature in Degrees, Rankine	Efficiency Factor	Initial Pressure
14.9	0.665	540.0	0.90	0514.5/
Mile Post MP	Elevation E	Quantity of Gas Q	Section Code	Pipe Code or Compression Ratio
0737.13	0320.0	00855.00	80	000000/
0737.12	0320.0	−00200.00	15	220000/
0725.00	1200.0	00000.00	15	220000/
0577.10	1285.0	00000.00	30	01.1370/
0577.10	1285.0	00000.00	85	000000 s

TABLE 2. Gas Pipeline Design Problem Solution.

Mile-post	Quantity of gas Mcf/day	Pressure psia	Brake HP	Sea Level HP	Fuel Mcf/day	Suction Pressure psia
737.12	655.00	514.54				
725.00	655.00	553.68				
719.00	655.00	580.42				
714.60	657.78	593.72				
702.00	657.78	626.80				
699.00	657.78	640.11				
691.50	657.78	657.91				
670.50	657.78	708.41				
639.20	657.78	782.83				
628.00	657.78	794.05				
628.00	660.76	619.66	10554	10554	2.98	614.66
606.30	695.76	671.21				
589.60	762.76	717.22				
577.10	762.76	752.85				
577.10	764.61	671.53	6907	6980	1.85	666.53

photoelectric reader. The Compute Switch is then turned to "GO," which starts computation. A self-loader in the first block of information read by the computer will continue the reading of the whole program and transfer succeeding blocks of information to the proper locations in the memory. The computer waits for the insertion of the data tape in the reader when this is through.

The data tape was prepared as explained above. When this tape is wound on a magazine and placed in the reader, the "p" key is again hit. The computation then proceeds without further intervention of the operator. In the event that a separate typewriter for preparation of the data tape is not available, the operator will type the information in Table 1 directly into the computer. As soon as the "s" key is hit at the end of type in, the computer will carry on its computations automatically.

As the data is read, the information is converted from decimal to binary. The routine recognizes the type of information read by the code number for each section. When an Initial Condition code is read, the constants appropriate to the problem are stored. In addition, computations are performed to obtain additional quantities, which are fixed throughout the problem by the initial conditions. The data pertinent to each section is stored in consecutive location in the memory for later use. Part of this data is an entry link for each section.

When the input operations are over, the first entry link is picked up and the calculations necessary for the first section are performed. The data to be typed out for this section are then converted from binary to decimal and stored in the output line. While this information is being typed, computation continues simultaneously for the next section. This results in an efficient program, permitting almost continuous computation with little time wasted waiting for type out to end before further calculations are made.

The computation for each succeeding section is determined by an interconnection routine that increments the "pick-up" command so that the entry link for the next succeeding section is obtained.

These calculations continue until the last stored word of information is reached, telling the computer that no additional data exists in the computer for processing. The computer halts operation as soon as type out is finished. If the problem has more than 28 sections, additional data will have to be read in. This will normally be the next block of information on the data tape. Read in of this additional information and computation will proceed by turning the Compute Switch to "Halt" and back to "GO." In this case, the initial conditions entered by the first block of information will prevail. If a new problem is read in, the new initial conditions will be specified by the first section of the block. Another set of calculations are then performed.

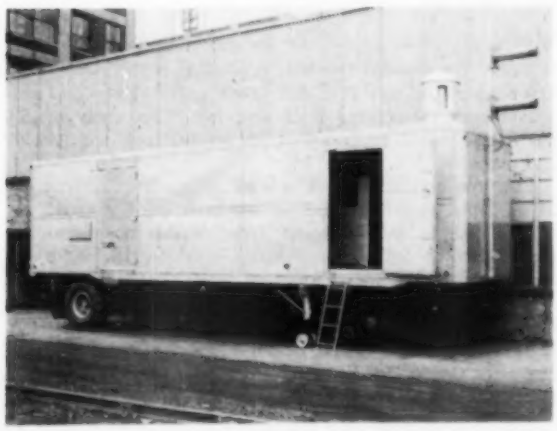
Conclusions to Example Problem

Less than 10 minutes were spent in the preparation of the data tape for this problem involving 13 sections. After the problem tape has been read in, the computer proceeds to call in data and type out answers at the rate of approximately 6 seconds per pipeline section and 10 seconds per compressor station. Therefore, the total time spent in preparation of the data tape, reading the problem into the computer, and typing out the answers, is under 12 minutes.

These figures are quoted to illustrate and exemplify the ability of an electronic computer in obtaining answers to a problem in a relatively short period of time. As mentioned above, a working program for a gas pipeline company will involve sophistications which will permit a more complete study of a system. Programming techniques are more involved for a larger program, and this example illustrates the power of a low cost computer, in assisting the design engineer.

Something New in STATION CONTROL

A COMPLETE remote centralized control and telemetering system for an unattended satellite pump station, permanently mounted in a trailer van, is a new idea for a pipeline control system being installed at Tufail, Saudi Arabia. A Centralized Transport Control system (Union Switch and Signal Division of Westinghouse Air Brake Company) will include electrical instrumentation, data processing units, tone shift terminals, UHF radio equipment, and a satellite station control and monitoring equipment. Mounted on the trailer van, this equipment will be hauled to the station site and wheeled into the desired position.



A portion of the remote control and monitoring equipment is shown mounted in the trailer van.

There it will operate in conjunction with supporting equipment, housed in two other similar vans, which includes a 5000-hp gas turbine, a crude oil pump, combustion air filtering equipment, measuring instruments, turbine sequence control, and generator.

Similar "package units" also will be installed at several unattended and automatic pumping stations along the same pipeline.

A CTC base station control cabinet will be situated at Abqaiq, many miles removed from the satellite station. This cabinet will include function switches, visual and digital readout of variables at frequent intervals, and, in addition, will print automatically this information on a standard, marginally punched continuous form on an electric typewriter to provide a permanent log.

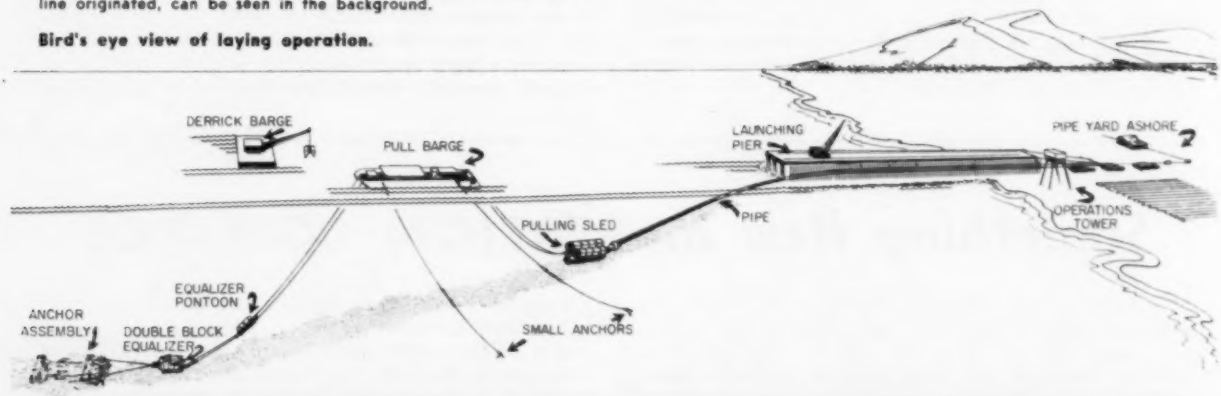
Variables that will be telemetered at the satellite and transmitted to the base control station include suction and discharge pressure, discharge pressure controller set-point, turbine inlet air temperature, and turbine speed. The information will be transmitted over an existing UHF radio network, which also provides a voice channel for voice communication between an inspection or maintenance crew at the satellite location and the base station personnel.

Launching pier. Fabricated pipe and general work area can be seen in this aerial view. The Hyperion Treatment Plant, where sludge line originated, can be seen in the background.

New Construction Ideas

Promise 100-Year Life For Offshore Pacific Line

Bird's eye view of laying operation.



The construction of a 7-mile, 22-in. line in the Pacific posed difficult problems — giving birth to dozens of new ideas

Here are some of them you'll find interesting:

1. *New way to spot coating damage the instant it occurs.*
2. *TV was used for underwater inspection and viewing during construction.*
3. *The line was designed for 100-year-life in salt water.*
4. *Unique, 40-ton sled that had several uses.*
5. *The line is the world's longest underwater pull and the deepest offshore installation.*

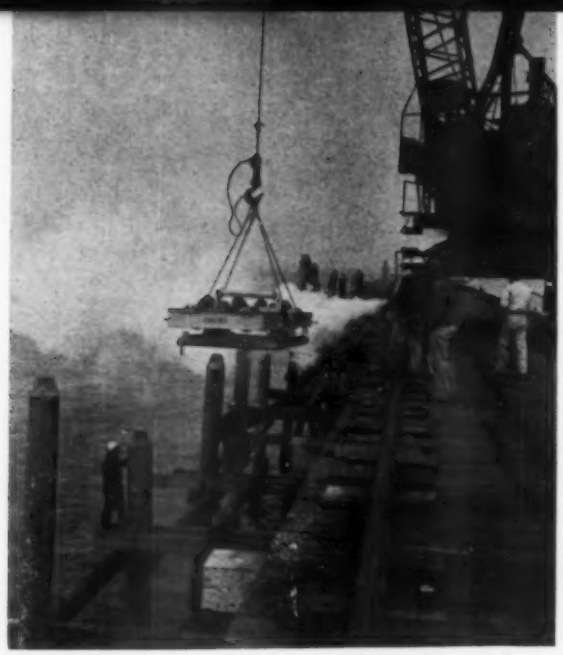
Donald M. Taylor
Gulf Coast Editor

VISIT any offshore pipeline job and you'll find new ideas at work. The reason? Offshore pipelining is still new — the first major line was laid just seven years ago — and improvements are coming thick and fast. Too, each project has its individual traits calling for special tools, equipment and methods.

Few jobs produced more new ideas than the construction of an underwater line laid off the coast of California recently. As you might expect, most of the ideas came as answers to the difficult engineering and construction problems posed by the line.

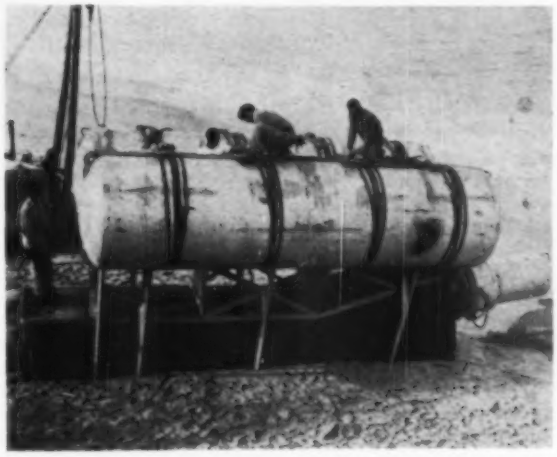
Engineering feature of the line. The line is 22 in. in diameter, 7 miles long and its open offshore end lies in 318 ft of water. It provides an ocean outfall for the sludge discharge of the City of Los Angeles, and it is perhaps the first steel line ever used for this service.

The most unusual feature of the line is that despite its corrosive environment — within and without — it is designed for a life of 100 years!



A large steam-powered crane lowers one of Collins' patented rubber-tired launching units onto the launchway extension alongside the 1000-ft pier constructed especially for this project.

Two views of sea going sled that will serve as anchor for permanent line. Pontoons reduce its weight to only 1000 lb in sea water.



Problems. Before we go over the new ideas that cropped up on this project, let's take a look at the problems that gave birth to them. The greatest difficulty and most severe limitation for the contractor came from the concrete coating. To protect the steel pipe from the line's own corrosive contents, designers called for a ½-in. cement mortar coating on the inside and for an external coating of 1⅛-in. of concrete to provide negative buoyancy and added protection from the ravages of salt water.

How did this affect construction? Engineers who designed the line, calculated that any bending sharper than that of a 2000 ft radius would likely crack and damage the coating. Moreover, they decreed that any imperfection in this coating would have to be repaired because otherwise the 100-year life expectancy of the pipeline might be impaired. This eliminated all but one of our present-day construction methods. For the only sure way to avoid sudden sharp bends that come from the surges of the tides and current was to pull the line along the bottom.

Yet an underwater pull provided anything but a simple solution to this undertaking. For one thing, no line this long had ever been pulled in one piece. Moreover, when the pull is along the bottom, the pipe should be kept moving as much of the time as possible, to prevent it from becoming sand and mud locked on the bottom. The solution to the latter problem is to weld the line up into long sections on shore so that there are a minimum number of stops for tie-in welds.

This is why the contractors at first dispaired of the small working area on the beach. There was a scant 600 ft between a busy California highway and the Pacific, but this problem, too, yielded to careful planning.

Construction of the Line

The mammoth risks of the job called for joint efforts. On the engineering side, three engineering firms formed a venture company called the Hyperion Engineers. At the same time, contractors formed the Healy-Submarine-DeLong venture company. The following companies composed it: Healy-Tibbits Construction Company of San Francisco, Submarine Pipeline Construction Company of Port Lavaca, Texas, and the DeLong Corporation of New York. For the most part, the actual construction procedures and equipment were supplied by Collins Construction Company of Port Lavaca.

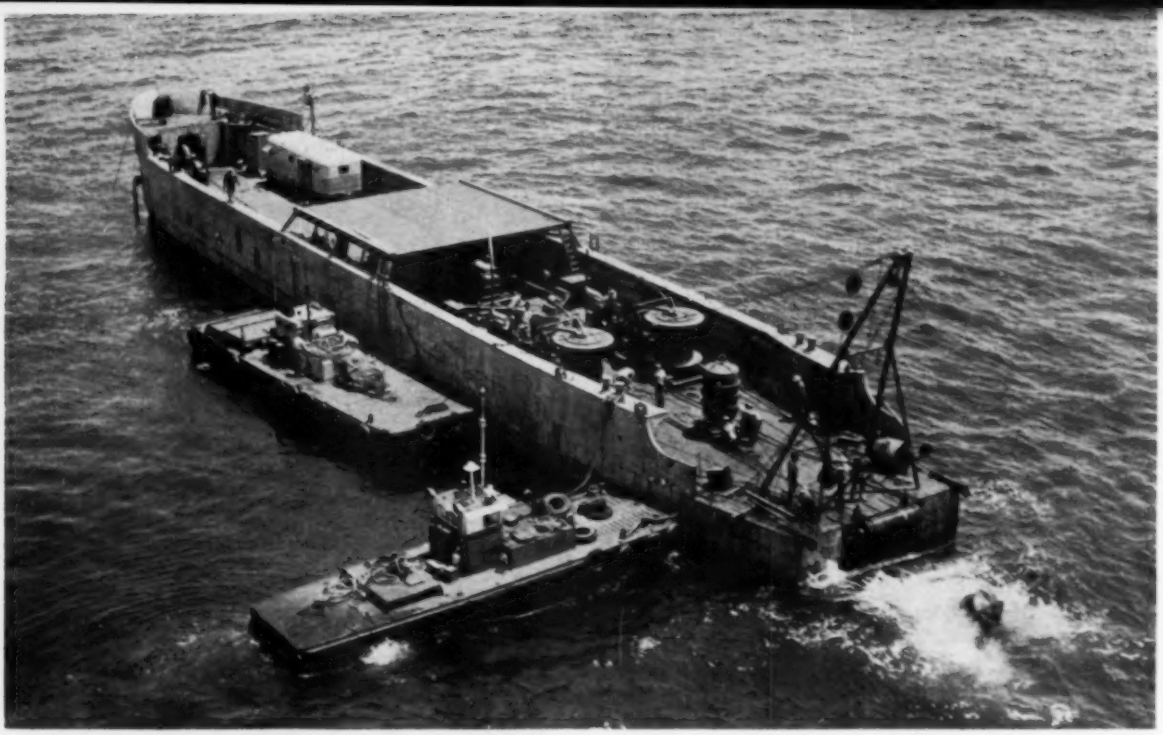
Basic construction plan. From the outset it was obvious to the contractors that a bad weld or a flaw in the internal coating would require repairs that could be financially ruinous. They countered this hazard with months of planning and testing. As a result the laying operation ran silky smooth.

Basically, the construction plan was simple: Install a heavy anchor assembly far offshore — two miles or so past the end of the line. Then lay wire ropes in toward the beach. Attach to a pull barge and inch the pipeline into the ocean in 1200-ft pulls.

Pipe fabrication details. The line was constructed of 22-in., ⅜-wall API 5LX-52 pipe. At the mill, each of the 927 joints that made up the 7-mile line, were internally coated with a ½-in. cement mortar lining. Externally, they were coated with a triple coat of enamel and glass fiber with a final wrap of pipeline felt. Over this outer protective coating 1⅛ in. of concrete was added for weight. The latter was reinforced with 12-gage, 2 by 4 galvanized wire mesh.

Variations in weight were limited to 40 lb per joint. This was necessary because the negative buoyancy of the line was critical. Too much weight might stall the pull, which was the world's longest. Too little might float the line, causing variation in alignment. Each joint weighed about 8500 lb, depending on its length. This gave a negative buoyancy of about 4 lb per ft.

Ingenuity in the pipe yard. The first task at the shore in-

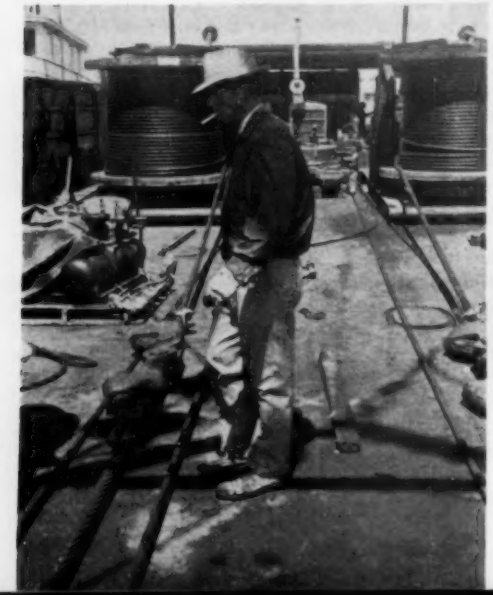


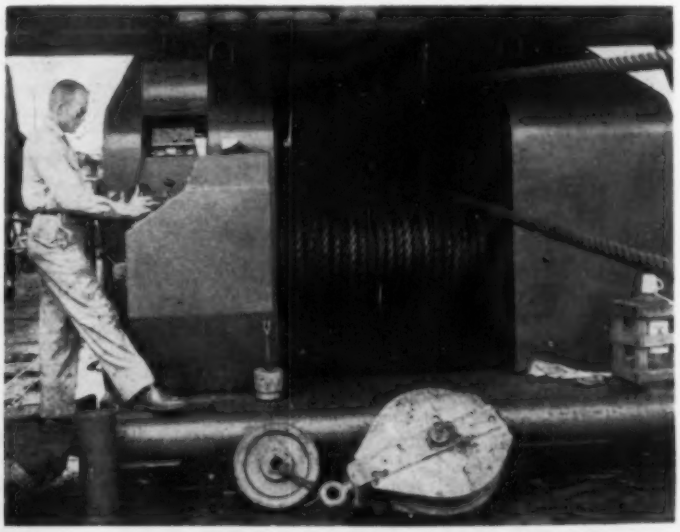
Pull barge at sea lays anchor lines. The ship works in toward shore spooling heavy wire rope anchor lines off the reels. Position of the barge is carefully maintained because pipe will follow the path of the anchor lines as it is pulled in the water.

stallation was to weld the pipe into 600 ft lengths so it could be launched rapidly. But, because of the delicacy of the internal coating, there arose the difficult problem of transferring the long sections onto the rubber-tired launching dollies without damage. The solution was ingenious. First, pipeliners added a hinged section to the end of each of the skids that supported the 600-ft lengths of pipe. They supported each of these skid extensions with a hydraulic jack so that the ends of the skids could be raised above the dollies. By spacing these movable skids between the dollies, tractors could roll the pipe sections up the skids, and when the pipe was directly over the rubber tires, the jacks could be released to lower the pipe onto the dollies. All of the jacks were manifolded together and each end of the movable skid was fitted with a shoe to prevent the pipe from falling off the end.

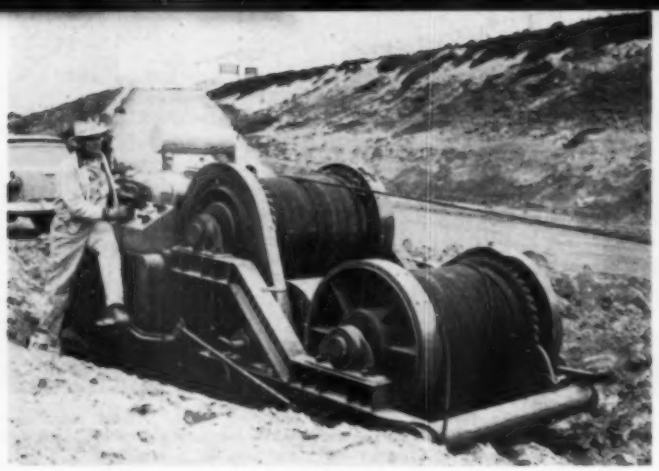
How the pipe was internally coated at the weld area. After each weld, the internal coating had to be extended across the weld area. The contractors sent men into the pipe to plaster this area with concrete mortar, but many factors made this unsatisfactory for the tie-in welds. A better solution was found before the job had progressed very far. Epoxy resin cylinders whose dimensions exactly matched the internal coating were cast in random lengths. Prior to each weld, workmen trued up the face of the internal cement mortar coating with carborundum disk saws. Then

The spooling devices in the background were used for spooling in the anchor cable as the barge moved farther out to sea after pulling successive 1200-ft sections of pipe from the launchway. Jean E. Johnson, general marine superintendent for Submarine Pipeline Construction Company, inspects one of the cables used in the pulling operation.

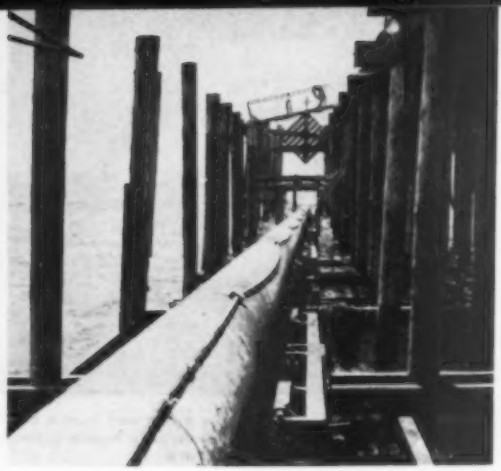




Giant air-operated pulling winch is capable of pulling a load of 1,000,000 lb using a double line. Twenty-five hundred feet of 2-in. cable can be spooled on each of its large drums. Marine foreman Thomas E. Broome is at the controls of Collins' mammoth Seamaster winch.



As the pipe was pulled, a restraining force of 20,000 lb was held by the hold-back winch (above). The steady tension prevented the pipe from running ahead of the pulling cable, and aided in maintaining accurate alignment.



Pipe moves into the sea down the launchway. Note the cathodic protection cable strapped to it. By monitoring instruments any imperfection in coating will show up because it will demand greater current for protection.

they measured the distance from the coating to the end of the pipe, and by making proper allowances for the weld gap, they could cut a length from the epoxy resin cylinder to exactly span the uncoated area at the weld. Just before the pipe was lined-up for welding, they smeared the uncoated area with eposy cement and inserted the cylinder. This gave almost perfect internal coating at this difficult area.

Launching trestle. The contractors constructed a 1000 ft offshore pier to aid them in launching the pipe into the rough Pacific. The upper tier of this structure provided a workway from cranes and tractors; the lower tier supported the rubber-tired launching dollies. Here, again, ingenuity solved a problem.

What would happen, questioned the pipeliners charged with launching the line, if a series of heavy waves should lift the line off the dollies and slam it into the pier? Damage, and plenty of it, they reasoned. So they set out to find a method of holding down the pipe—regardless of the pounding surf. The solution was ready-made. They simply turned a number of the launching dollies upside down and bolted them to every fourth or fifth upright dolly near the end of the pier. The resulting hold-down was not only adequate but virtually frictionless so far as the launching was concerned.

Anchor assembly for the pulling operation. The anchor assembly placed in 660 ft of water two miles or so beyond the proposed end of the line was designed to withstand a pull of about 1,000,000 lb, according to S. V. Collins, president of Collins Construction. The design was based on an analysis of the soil at the anchor point. The construction of the assembly is shown in an accompanying drawing. Two 30-in. "I" beams, 42 ft long were fitted with four flukes each, and these "beam anchors" were bridled in tandem, 120 ft apart with four 14,000-lb Danforth anchors — two on each side — spaced between them. This assembly weighed 160,000 lb. It was attached to a 2-in. wire rope bridle to a buoy and anchor block that formed the end of the main anchor cables.

The anchor lines. Two wire rope anchor lines, graduating from 2-in. at the outer end to 1¼ in. at the beach end, were laid from the anchor assembly toward the shore. This operation was conducted under the watchful eye of a transit trained along the path of the proposed pipeline, because once the anchor lines were laid the path of the line was fixed.

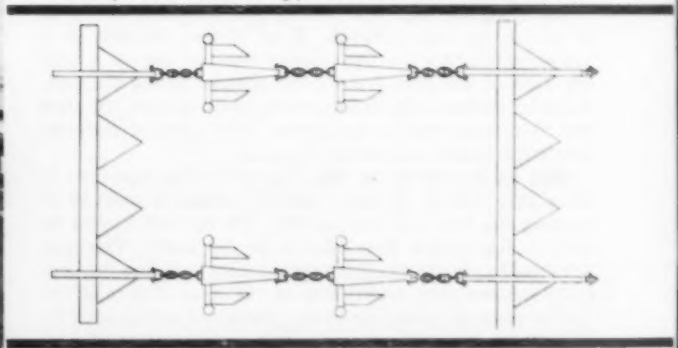
How the line was pulled into the water. Near the shore, an 8500-ft length of 2-in. wire rope was spooled ashore and attached to the block on the pulling sled, fixed permanently to the end of the pipeline. Each end of this 2-in. wire rope was attached to a drum on the 320-hp winch on the pull barge, and the offshore end of main frame of this winch was attached to the anchor lines with carpenter stops. Thus the pull, exerted as the line was snaked into the water was not transferred to the pull barge. The only vector affecting it was vertical, causing the barge to settle deeper in the water as the tension of the pull increased.

There were two welding stations on the launchway making it possible to launch the pipe in 1200-ft pulls.

Moving the pull barge. During a pull the barge was anchored, held laterally by its own light anchors, and held against the pull by the two anchor lines running from the offshore anchor assembly. After one pull was completed and preparations were being made for the next, the power from

Pipeliners inspect special anchor prior to placement.

Anchor block assembly. The two special anchors at the ends were made of 30-in. I beam. The four flukes were made out of steel plate set at the proper angle for greater holding power. Note the four 14,000-lb Danforth anchors coupled in between. Total weight of the anchor assembly is 160,000 lb, holding power is better than 1,000,000 lb.



Underwater TV. View of the nose of the sled from a depth of 300 ft. Divers carried underwater TV cameras to enable supervisory personnel at surface to inspect work below.

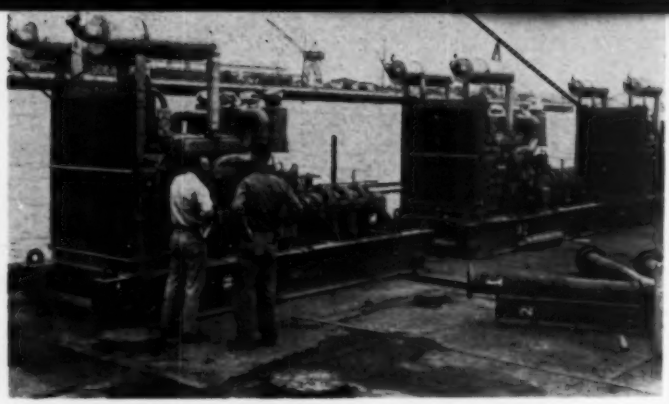
Trenching operation. About 6000 ft of the line nearest the shore was buried 2 to 15 ft by this trenching machine.

the winch was transferred to two reels attached to the anchor lines. This enabled the pull barge to move ahead along the path of the pipeline, and, as it moved ahead, it kept tension on the pipeline through the brake on the two-drum winch.

Hold-back winch. While the pipe was being pulled, a restraining force of 20,000 lb was held by the hold-back winch. This tension prevented the pipe from running ahead of the pulling cable and helped maintain an accurate alignment during the pulling operation. After a 1200-ft section was in the water, hold-back clamps were attached to the end to maintain tension on the line while the succeeding section was being welded up.

The sea-going sled. The pulling sled, weighing 62,000 lb in air, served two purposes. First, it was designed as a permanent anchor for the finished line and second it held the nose of the pipe 3 ft off the bottom during the pull. Made of concrete and steel, it completely isolated the steel line from construction equipment. This allowed cathodic protection monitoring during the pull.

Plug on the end of the line. The end of the pipe rests in more than 300 ft of water, and an orthodox method of capping the end was not feasible. Yet the line had to be tested, pigged, and then opened to the water. This was achieved by incorporating a tapered receptacle into the end, and a tapered plug, sealed with an "O" ring. This plug was held in place by a back-up drum, positioned and secured by a hook hinge at the top and a bolt at the bottom. An injection pig was placed in the end of the line and connected to the plug. The bolt securing the back-up drum was calibrated to break at a pressure slightly greater than test pressure. After the test was completed, the line pressure was increased, the bolt yielded, and the pig ejected the entire assembly off the end of the pipe.



Power for the trenching machine. These 300-hp centrifugals supply necessary water pressure for operating trenching machine. They pump 6000 gpm.

How to detect coating damage the instant it occurs. A cathodic protection cable was run with the line as it was launched into the water. By keeping the line under constant cathodic protection, any breaks in the coating would instantly show on the instruments monitoring the current demands.

Pigging the line as it was launched. A sizing pig was pulled through the line as it went into the water. Any break in the internal coating would have shown up before the pipe entered the water.

Bad weather operation. During the laying operation, the swells ran from 3 to 8 ft with seas from 2 to 6 ft in addition to the swells. These seas in no way interferred with operations, which continued around the clock.

Underwater TV. From time to time, the construction forces sent divers underwater for inspection purposes. They carried an underwater TV camera that allowed the men in the barge to view the line.

Laying time. Although the preparations for the job consumed months, the actual laying time ran slightly over seven days. ★ ★ ★

S. V. (Sammy) Collins, president of Submarine Pipeline Construction Company, Inc., is being congratulated by R. R. Helen, project manager in behalf of Healy-Submarine-DeLong, a joint venture, for completion of the 7-mile installation in the record-breaking time of 7 days, 11½ hours.

Part 2

Bureau of Mines' studies in two fields result in conclusions regarding type of tests that will give best deliverability data

How Gas Storage Wells Behave

C. J. Walker, E. R. Corliss, J. S. Miller, and H. N. Dunning

U. S. Bureau of Mines, Petroleum Experiment Station, Bartlesville, Oklahoma

The series of withdrawal tests were complemented by back-pressure tests during gas injection. As a result of early studies during injection and withdrawal cycles, it was reported that the direction of flow often had no detectable effect on the values of "n" but that injection rates were about five percent below withdrawal rates at corresponding pressures.[5] These workers also report an example in which the "intake" back-pressure curve is displaced toward the pressure axis from the "withdrawal" curve and has a slightly higher "n" value. In the reservoirs studied, this would appear to be the rule. For example, the average "n" and "C" values for the wells of the Bridgeport project at a shut-in pressure of about 150 psia were 0.640 and 9100 during withdrawal operations. The corresponding values during injection were 0.720 and 3500.

Fig. 4 illustrates the range of differences in injection and withdrawal back-pressure curves in the Bridgeport reservoir. With one exception, the "injection" values of "n" are higher and those of "C" are lower than for the withdrawal curves. Friction in the flow string decreases the flowing wellhead pressure during withdrawal and increases it during injection, relative to the sand-face pressure. Therefore, the data shown in Fig. 4 were used to calculate the back-pressure curves at bottom-hole conditions; however, corrections to bottom-hole conditions caused changes so slight as to be barely discernible on the plots. The small differences in well behavior during injection and withdrawal may result from different rates of approach to stabilization or to physical changes caused by foreign material. This effect will be investigated in further tests.

The back-pressure curve presumably reflects changes in well behavior. Changes that result in small differences in gas flow, however, are extremely difficult to separate from slight variations in procedure, or experimental variables. The method is most useful, however, for establishing the nature and extent of major changes in well be-

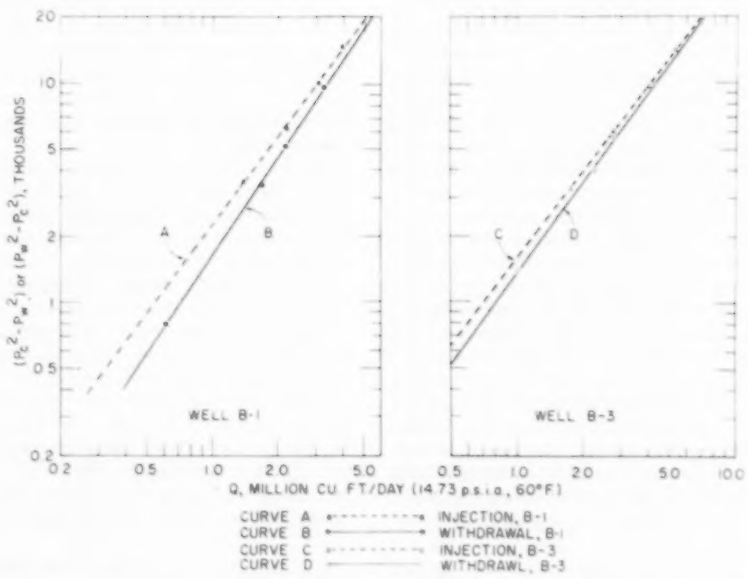
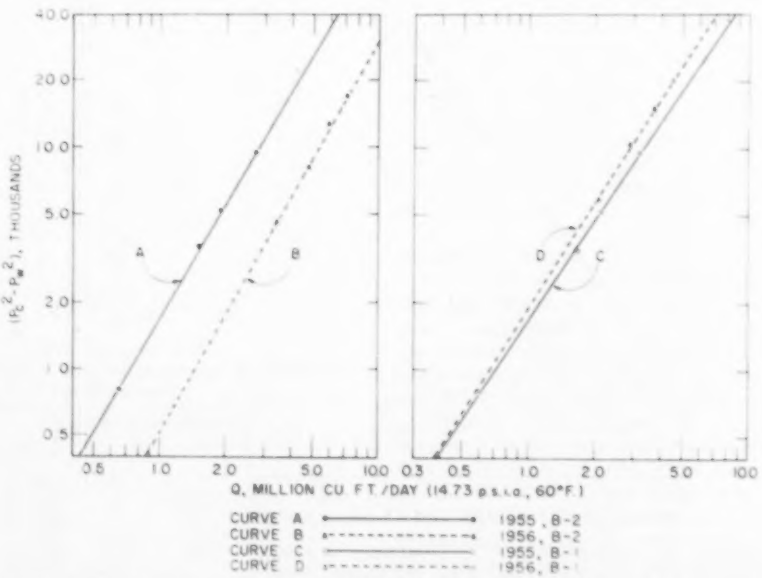


FIG. 4. **Back-pressure curves** during injection and withdrawal cycles. (Wellhead conditions.)



F.G. 5. **Back-pressure curves** showing effects of change in completion of Well B-2 compared to unchanged Well B-1. (Wellhead conditions, withdrawal.)

havior. An example of such application is shown in Fig. 5. This figure compares the results of back-pressure tests, in 1955 and 1956 during withdrawal cycles, on wells B-2 and B-1. The curves for Well B-1 show only slight differences in behavior although the average shut-in pressure was about 150 psia in 1955 and 500 psia in 1956. Between the tests, Well B-2 was drilled deeper, increasing the exposed productive sandface by about 50 percent.

The curves for the well reflect the change in deliverability of the well. The least squares method[5,16] was used to arrive at the best straight lines through the two sets of points. Curve A (1955) has an "n" value of 0.580, a "C" value of 13,500, and a "Q_{10}" value of 2.81 million cu ft per day. Curve B has an "n" value of 0.560, a "C" value of 30,500, and a "Q_{10}" value of 5.30 million cu ft per day. Statistical tests of the experimental data[17] show that this small difference in slopes is not significant. Therefore, this test shows that when the depth of the pay sand was increased, the "n" value of the back-pressure curve was not changed but the "C" value and "Q_{10}" value were approximately doubled. Whether or not such correlations are generally true requires further tests for corroboration.

Isochronal performance. Wells tested stabilized rapidly, as might be expected for wells in a highly permeable formation. Wells U-1 and U-2 had stabilized before the end of the two-hour periods. Curve A, Fig. 6, is the isochronal performance curve for Well U-1. This well stabilized so rapidly that the points obtained at each of the successively greater intervals fall on the same curve.

Actual performance of Well U-1 from October 1954 through February 1955 is indicated by the "production points" on Fig. 6. These points are in good agreement with the 1956 test results but indicate lower deliverability than predicted from the results of the preceding 1954 tests. Production points of wells U-2, U-3, and U-7 were similarly displaced from the respective test results except that the displacement was somewhat greater in the wells with slower stabilization characteristics. The actual deliverability curves deviate from test results in an expected manner; calculations of long-term stabilized curves also result in data that are displaced toward the pressure axis from the test data.

Well U-3 reached stabilization at the lowest flow rate after 1.5 hours and was approaching stabilization at the higher rates at the end of the two-hour period. Well U-7 stabilized rather rapidly but slowly enough that separate isochronal curves were obtained.

Isochronal performance curves for this well are shown by curves A-E in Fig. 7. These curves are typical of those obtained by the isochronal method, having practically the same "n" values (0.760 to 0.730) and being displaced toward the pressure axis as the period is increased. The value of "C" decreased from 3200 to 2700 and the value of "Q_{10}" decreased from 3.2 to 2.3 as the periods increased from 0.25 hour to 2.0 hour. Examination of these curves shows that the well is nearly stabilized at the end of the two-hour period. The isochronal curves are compared to the conventional back-pressure-curve (curve F) which was determined the following day. The characteristics of this well determined two years earlier, together with similar data for the other wells tested, are summarized in Table 4.

The "Q_{10}" values determined from the conventional back-pressure curves determined during the 1956 test series are in good agreement with those from the two-hour isochronal performance curves determined the preceding day. The values of "n" for the isochronal curves also are in fair agreement with the corresponding values determined two years earlier, except for that of Well U-2. A large change in the "C" and "Q_{10}" values between the 1956 and 1954 tests is observed; the "C" values of the 1956 tests average about one-half the corresponding values determined in 1954 whereas the "Q_{10}" values determined in 1956 average about 35 percent less than those determined in 1954.

The decreases in deliverabilities of these four wells from 1954 to 1956 are larger than would be expected from experimental errors and may indicate some deterioration of these wells during the two-year interval, probably because of the accumulation of water, compressor oil, or other interfering sub-

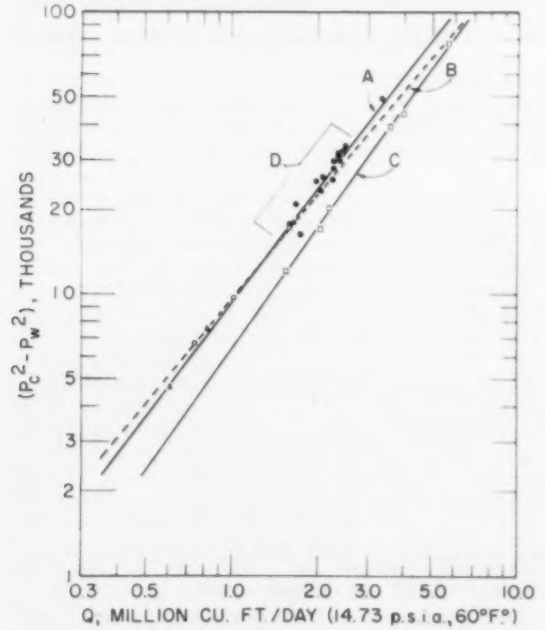
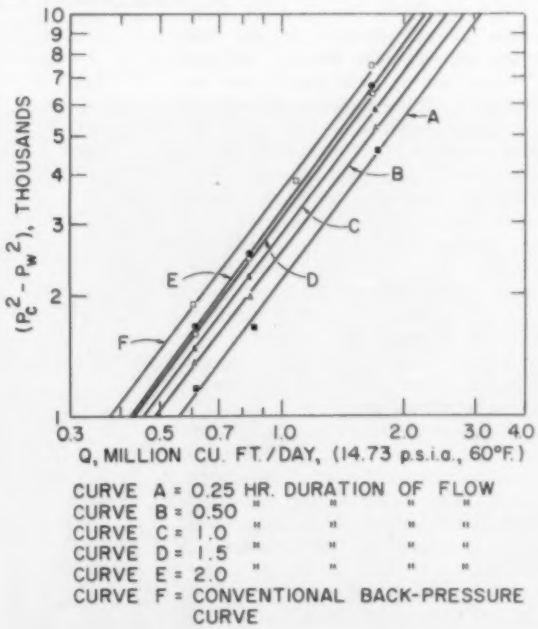


FIG. 6. **Isochronal performance,** back-pressure, and production curves for Well U-1.

FIG. 7. **Isochronal performance curves** and conventional flow-after-flow curve of Well U-7.



stances in the formation around the wellbore.

These limited results indicate that there is little reason for preferring the isochronal method over the conventional method for wells that stabilize rapidly such as those in most storage reservoirs. This is in agreement with the results of Cullender[9] who developed the isochronal method for use in reservoirs of low permeability.

Conclusions

The results of series of back-pressure tests on groups of wells in two gas-storage projects verify earlier observations that the individual wells in a single reservoir differ in deliverability characteristics. The "n" values of the back-pressure curves fall in a rather narrow range and vary about as much in a single reservoir as in the two reservoirs tested. The "C" values and deliverabilities of single wells within a single reservoir vary widely. However, composite curves prepared from the individual well curves plot as straight lines on log-log paper allowing generalizations of the behavior of the wells as a group.

These generalizations show that, for gas-storage projects in shallow reservoirs, there is little advantage in making the extensive calculations required to correct the back-pressure curves to bottom-hole conditions. It is concluded that for most purposes, wellhead deliverability tests are more practicable than those based on bottom-hole conditions.

A new measure of deliverability, called the "Q_{10}" value, is suggested as a replacement for the "open flow" and "C" values that have been use previously. The "Q_{10}" value is defined as the rate of flow of gas from a well when $(P_c^2 - P_w^2)$ or $(P_f^2 - P_s^2)$ is equal to 10,000. This value, unlike "open flow" and the "C" value, does not involve extended, and often unjustified, extrapolation of the back-pressure curve. Results of these tests and reference to the literature show that this level of pressure difference is generally near or within the range of back-pressure tests. Furthermore, the "Q_{10}" value results in conclusions regarding well deliverabilities in agreement with conclusions from the back-pressure curves.

The back-pressure curves obtained during injection generally are displaced slightly toward the pressure axis and have slightly larger "n" values than corresponding curves obtained during withdrawal.

The "n" values of back-pressure curves determined on a well before and after it was drilled deeper into the storage formation did not show a significant change. The latter curve, however, was displaced away from the pressure axis considerably; the "Q_{10}" value increased from 2.80 to 5.30 million cu ft per day. These results indicate that deliverability is a direct function of sand-face thickness whereas it is likely that "n" is a function of the physical properties of the formation and of the flowing fluid.

Four wells of the Ulan project were studied by the isochronal performance method. These wells stabilized rapidly but at slightly different rates. One well stabilized so rapidly that the isochronal curves determined at different periods plotted as a single curve. The isochronal curves determined for another well formed a typical pattern, all having about the same "n" value but being displaced toward the pressure axis as the periods were extended. The two-hour isochronal curve for the well was in good agreement with the conventional back-pressure curve. Essentially the same results were obtained in tests of the other two wells. The results of the isochronal and conventional back-pressure tests were compared to actual well performance and were found to be in fair agreement.

TABLE 2. Summary of "n" and "C" Values[1] for Back-Pressure Curves of 7 Wells and Composite Curves, Bridgeport Gas-Storage Project.

Wellhead, March 1955[2]	Individual Wells		Composite
	Range	Average	
n	0.500– 0.765	0.640	0.650
C[3]	650–13,800	9,100	50,400
Bottom-hole, March 1955			
n	0.500– 0.765	0.650	0.665
C	650–13,100	8,300	44,800
Wellhead, November 1956[4]			
n	0.550– 0.700	0.600	0.585
C	1,200–30,500	14,700	96,200
Bottom-hole, November 1956			
n	0.565– 0.700	0.610	0.600
C	1,100–29,300	13,000	85,800

[1]Equation 3.
[2]Shut-in pressure, 150 psia.
[3]Cubic feet per day (14.73 psia, 60 F).
[4]Shut-in pressure, 500 psia.

TABLE 3. Average of "n" and "Q_{10}"[1] Values[2] for Wells of Ulan and Bridgeport Gas-Storage Projects (Wellhead Conditions).

Well No.	Ulan Project		Bridgeport Project	
	n	Q_{10}	n	Q_{10}
1	0.695	1.40	0.655	3.14
2	.590	3.56	.570	[4]4.05
3	.705	5.17	.665	4.09
4	650	2.21	.585	2.78
5	.715	0.75	.550	1.32
6	.685	0.32	.595	4.65
7	.715	3.00	.730	0.75
8	.740	0.30		
Average	.685	2.09	.620	2.97
Average No. wells		16.72		20.79
Composite	.680	16.68	.620	20.78

[1]Million cu ft per day at $(P_c^2 - P_w^2) = 10,000$.
[2]Equation 3.
[3]1955 "Q_{10}" = 2.80; after redrilling "Q_{10}" = 5.30.

TABLE 4. Comparison of Isochronal Performance with Conventional Back-Pressure Curves (Wellhead Conditions, Ulan Reservoir).

Well	Isochronal 2-hr periods, 1956			Conventional back-pressure 1956			Conventional back-pressure 1954 (Average)		
	n	C[1]	Q_{10}[2]	n	C	Q_{10}	n	C	Q_{10}
U-1	0.750	1,500	1.45	0.815	600	1.05	0.695	2,300	1.40
U-2	.715	2,300	1.64	.580	8,300	1.70	.590	15,900	3.56
U-3	.735	4,000	3.50	.820	1,900	3.55	.705	8,300	5.17
U-7	.730	2,700	2.30	.745	2,200	2.10	.715	4,200	3.00

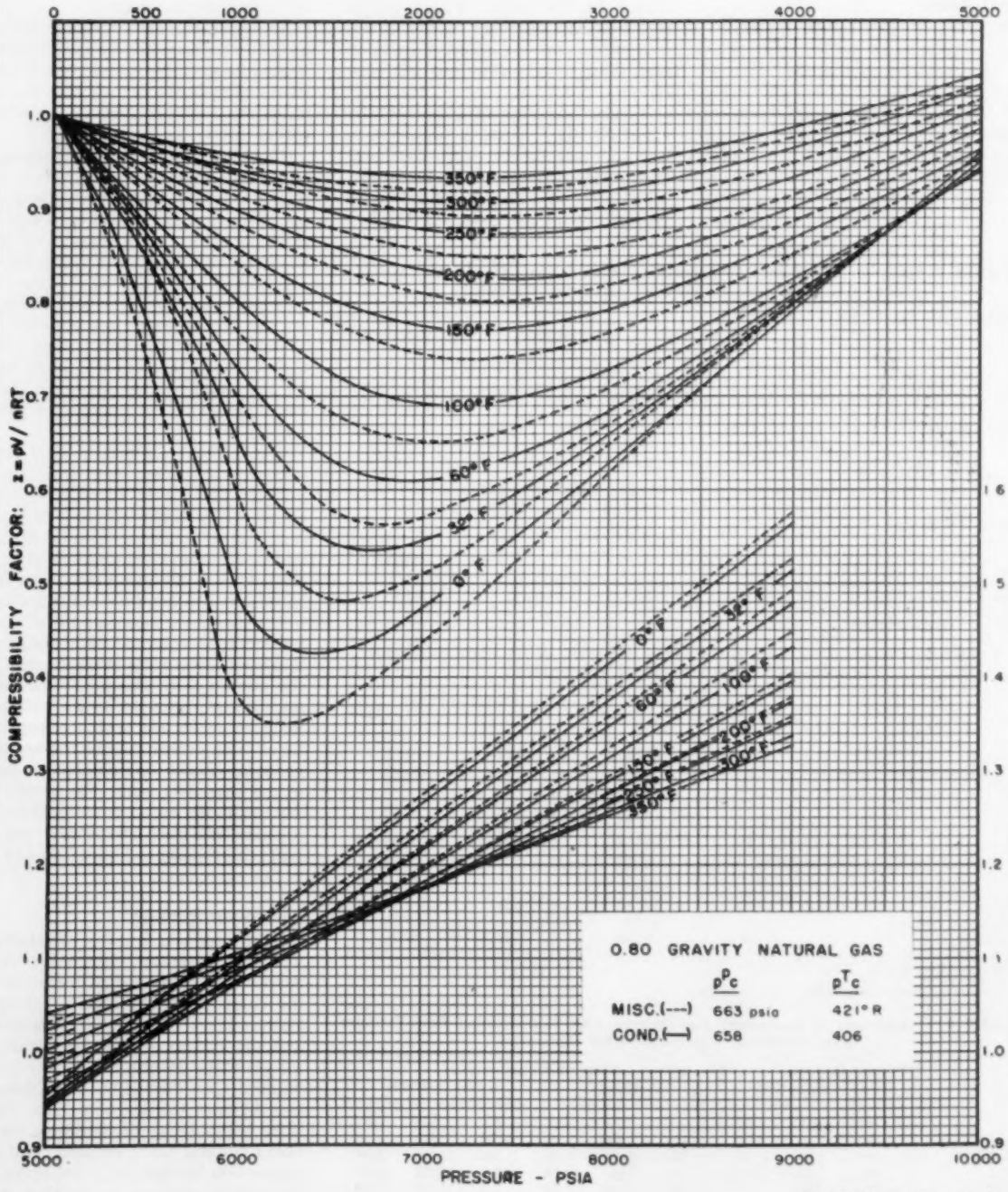
[1]Cubic feet per day when $(P_c^2 - P_w^2) = 1$.
[2]Million cubic feet per day when $(P_c^2 - P_w^2) = 10,000$.

Acknowledgment

This work was done in cooperation with the American Gas Association. Advice and assistance of members of the Underground Storage Committee, Deliverability Problems Subcommittee and the Project Advisory Committee are gratefully acknowledged. The Hope Natural Gas Company, Consolidated Gas Utilities Corporation, New York State Natural Gas Corporation, Oklahoma Natural Gas Company, and the Union Gas System, Inc., cooperated in the testing program by making their personnel and facilities available for field tests. ★ ★ ★

SIMPLIFIED COMPRESSIBILITY FACTOR CHARTS FOR NATURAL GAS CALCULATIONS

CHART 4



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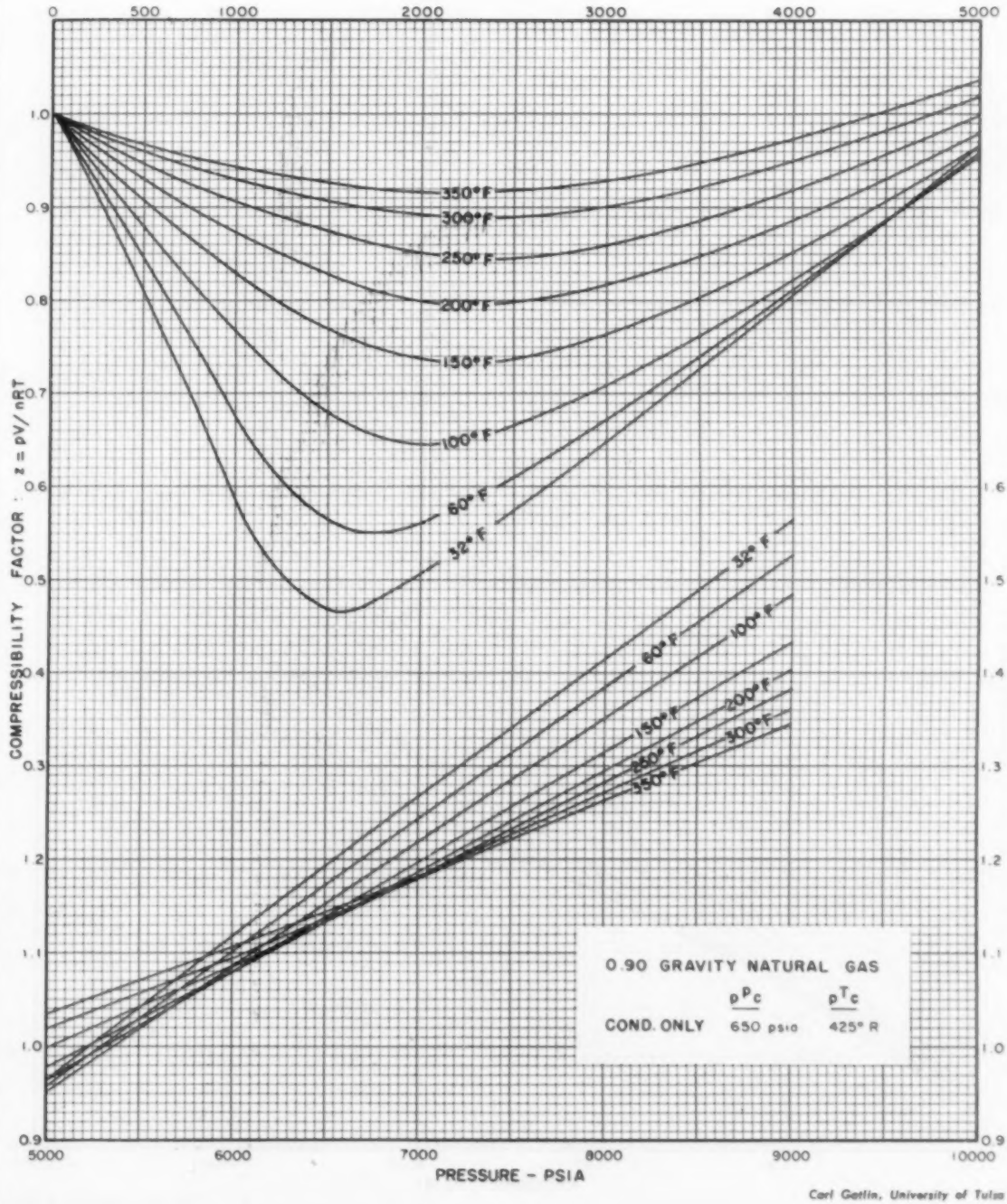
SIMPLIFIED COMPRESSIBILITY FACTOR CHARTS FOR NATURAL GAS CALCULATIONS

CHART 5



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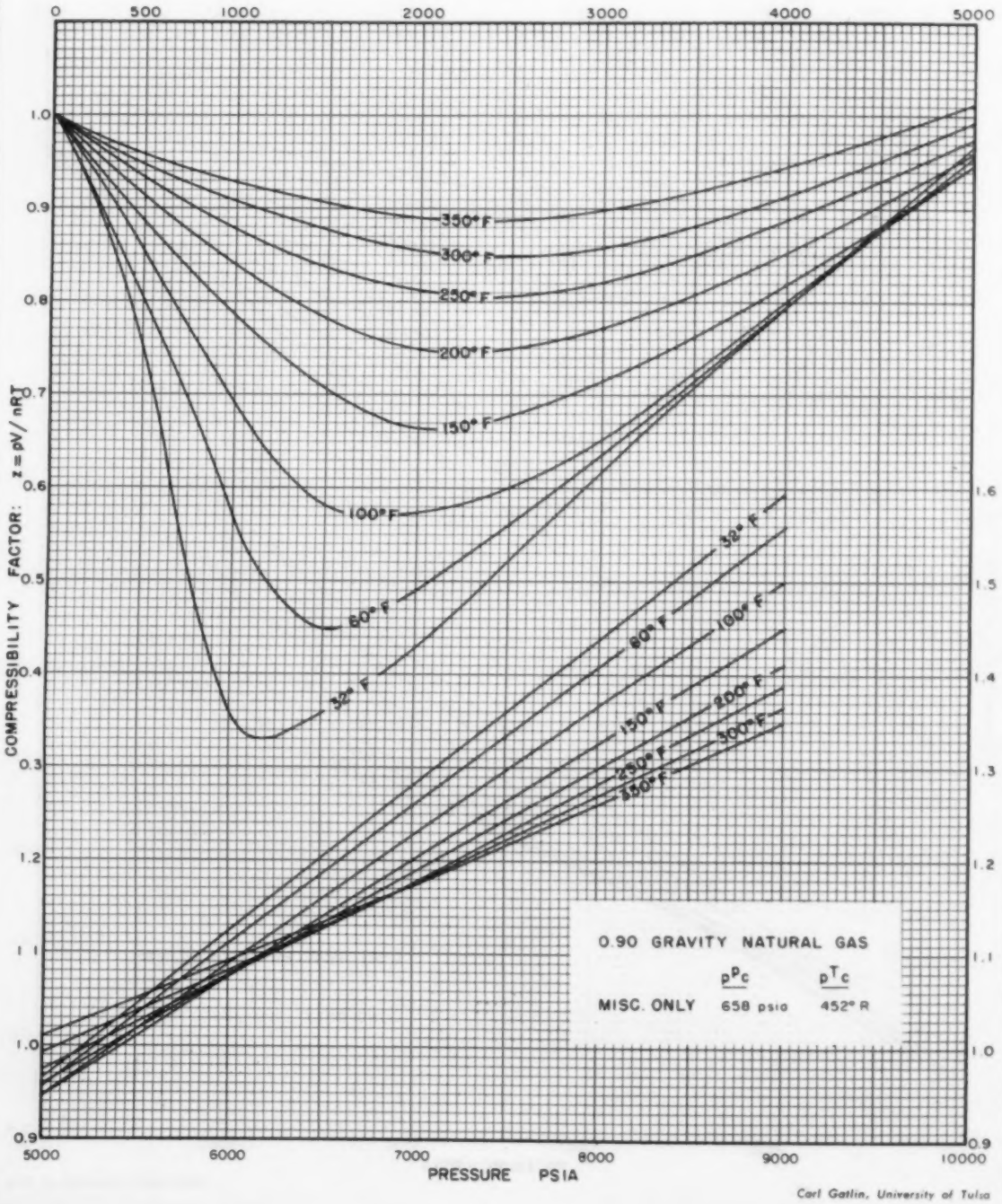

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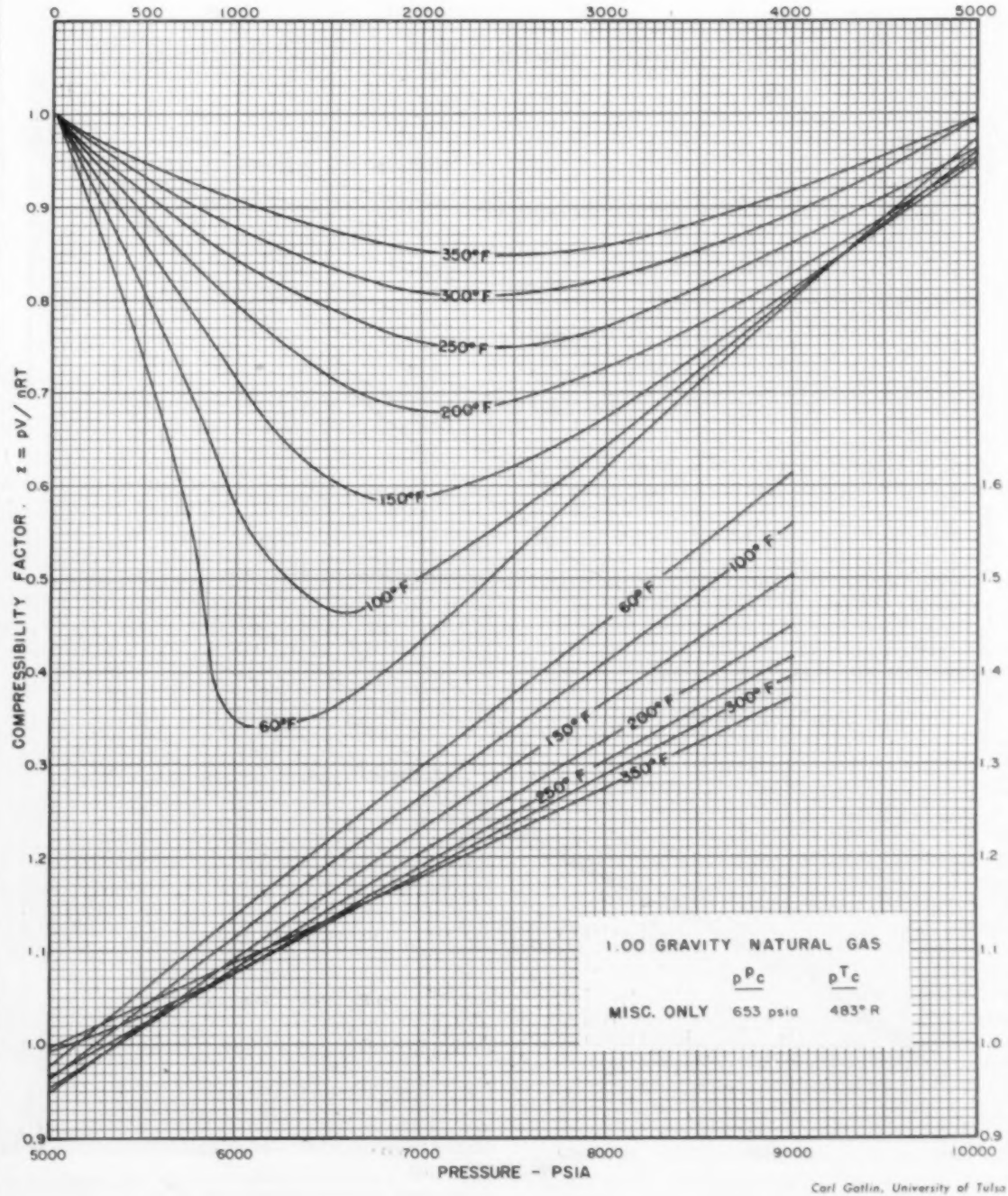
SIMPLIFIED COMPRESSIBILITY FACTOR CHARTS FOR NATURAL GAS CALCULATIONS

CHART 7



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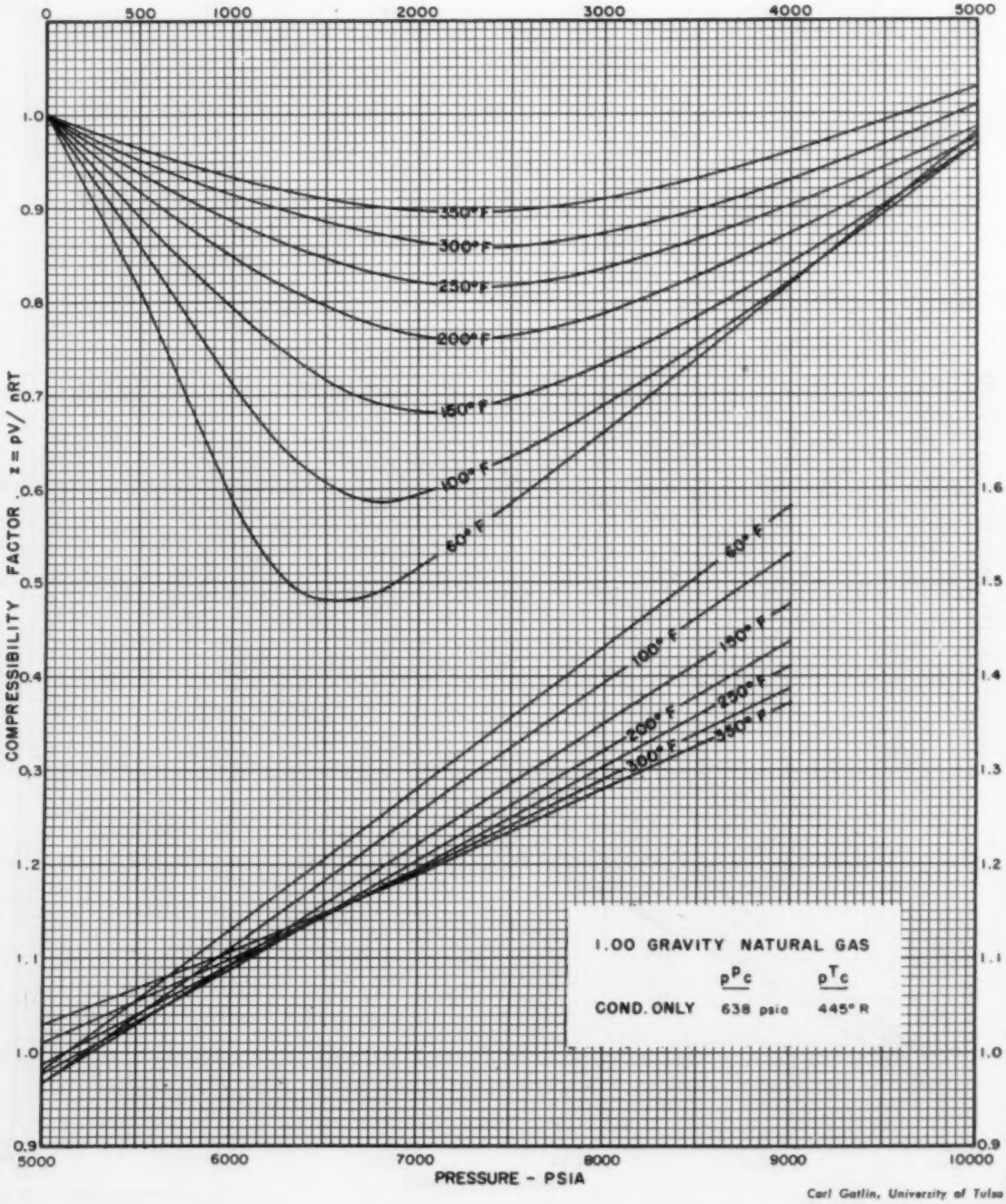
SIMPLIFIED COMPRESSIBILITY FACTOR CHARTS FOR NATURAL GAS CALCULATIONS

CHART 8



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P 615.371

River Crossing Construction Methods

No two are alike. Here are some of the techniques and examples of their application

Typical River Crossing? There's hardly such a thing as a typical one because crossings for the most part are tailor made and individual. For the most part they are a mixture of the methods discussed here.

Donald M. Taylor
Gulf Coast Editor

THE old saying, "There's many a way to skin a cat," certainly holds true of pipeline river crossing construction methods. There's hardly such a thing as a **typical** crossing, and the construction practices usually change from job to job.

There are a number of reasons for this. The streams vary in depth, width, swiftness, etc., and the men who design and construct the crossings vary in ideas, equipment, etc. Also, pipeline companies and contractors are pouring creative thinking and copious engineering study into crossings — especially the major stream crossings. The result is that most crossings are more-or-less "customized."

Why is so much effort being channeled into river crossings? The river crossing is the soft under belly of the pipeline system. Let one fail and a company may be out of business for an extended time. Failure of a major crossing during the flood season could be catastrophic for a gas company.

Aside from their critical nature — a pipeline river crossing is expensive. On a per foot basis, their cost may run as high as 25 times that of ordinary cross-country pipelines of comparable size. Sometimes their magnitude is amazing, even to the pipeliners who construct them. Take, for example, a 1200-mile-long, 30-in. gas pipeline system constructed a few years back. Someone in this company's public relations department calculated that the ditching operation required the handling of 19,000,000 cu yd of dirt. But of this amount, more than 12,000,000 cu yd was accounted for by the river crossings that comprised but a fraction of the line's length!

So it is easy to see why companies try to make each crossing better than the last — and cheaper at the same time. This is why most major crossings are "tailor made"; following, perhaps, one of the general construction patterns discussed below, but varying widely from it at the same time.

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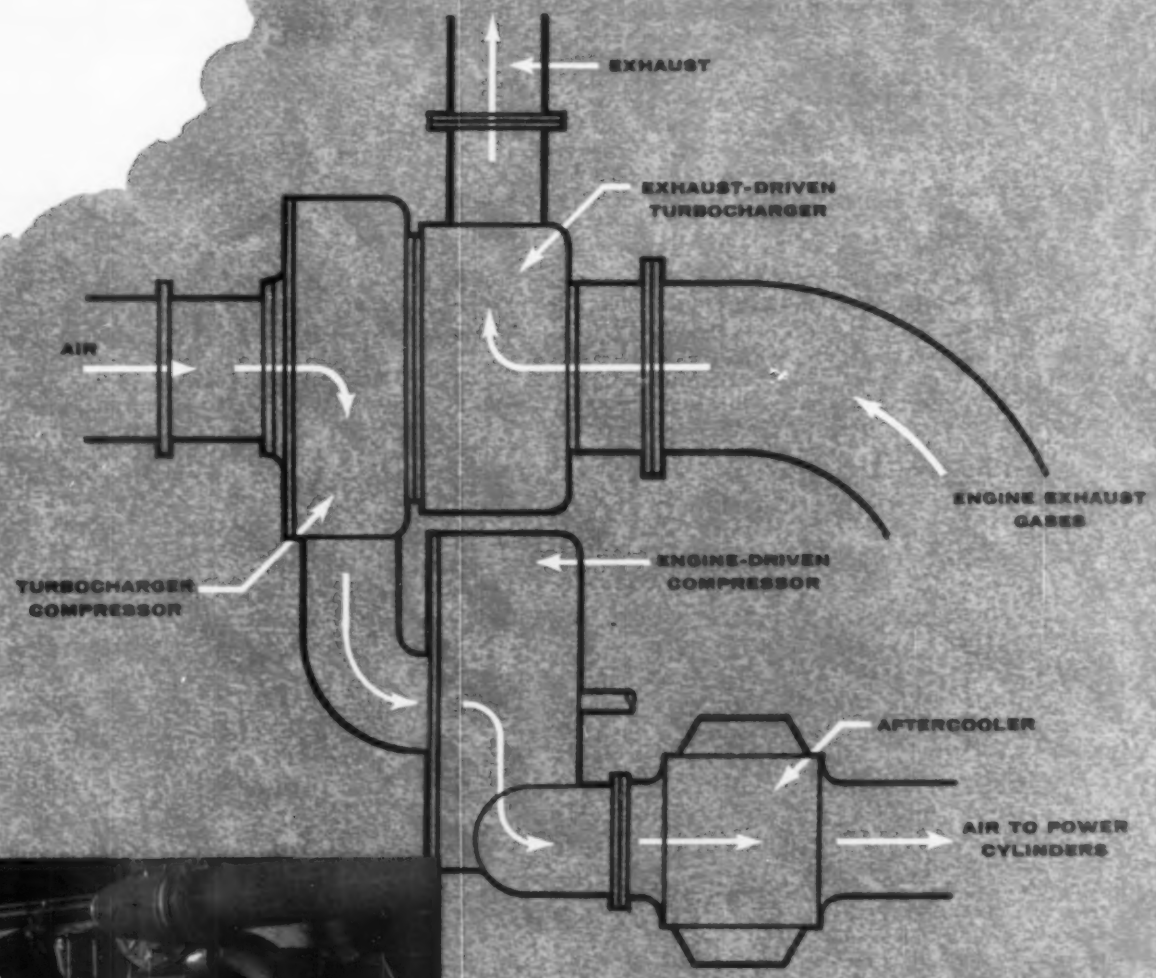
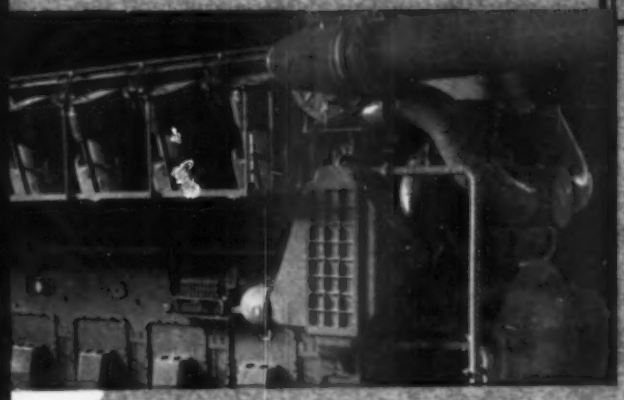




Operational Diagram of Cooper-Bessemer Series Turbocharging

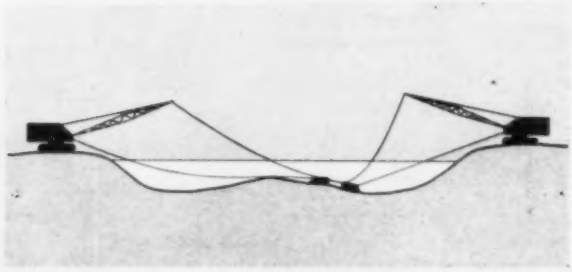
Pulling or Shoving the Line Along the Bottom of the River

This is the most common of all river-crossing techniques. It has been used on everything from creek crossings to the four-mile crossing of the Straits of Mackinac. Crossings made in this manner number in the thousands.

Where the crossing is narrow and shallow, the pipe is usually welded up on shore, coated, weighted, and pulled or shoved through the ditch across the stream. But the major stream crossings require a more elaborate technique. The ditch may be an upstream or downstream catenary or run straight across. Usually, engineering plans permit little deviation from the plotted course of the line. The pulling operation in this case must be carefully executed, and chances are the negative buoyancy during the pull must be lightened.

HYPOTHETICAL EXAMPLE OF A SMALL STREAM CROSSING

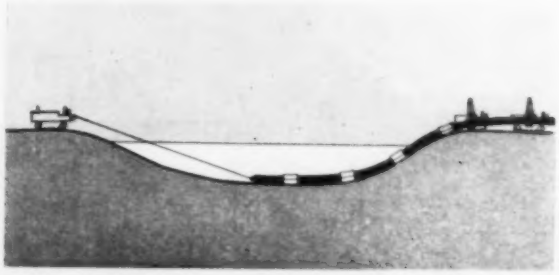
The problem. Let's make a hypothetical crossing of a fairly small stream using this technique. We'll say our task is to lay a 24-in. line across a 200-ft wide Alabama stream during the dry season. Its depth runs about 11 ft in the center and the bottom is composed of silty clay, which will stand up well under the sluggish flow. Specifications call for a ditch of sufficient depth to provide a minimum of six feet of cover. The banks are shallow.



Ditching. We have several choices. We could have pontoons shipped out for this special purpose, or we could haul logs from five miles down the right-of-way and lash them together with wire rope to form cribbing for a temporary bridge. In both cases we could use clamshell buckets to cut the ditch. Both of these methods provide the advantage of having a bridge across the stream over which the pipeline spread can cross. But let's say there's a highway bridge nearby that will serve nicely for this purpose, and all we need do is lay the crossing.

In this instance, we'll "Yo-Yo" the ditch. By spotting draglines on opposite sides of the stream, and cutting the ditch to grade as far from the bank as the draglines can cast their buckets, we can get the major part of the crossing. Next, we tie the two buckets together with wire rope as shown in one of the illustrations, and as one of the draglines pulls in, it pulls the other's bucket out. Thus, we cut the center portion of the crossing, and then turn our attention to polishing up the approaches.

Land operations. The crossing requires a slight sag bend near the middle of the section. The bending machine from the pipeline spread makes this bend, and we weld up the crossing—shaped to the contour of the ditch. Next, we bull-plug both ends of the section and test it hydrostatically. Then comes a double coat of glass fiber and pipeline enamel, followed by an asbestos felt outer wrap. We add concrete, or cast-iron river weights at specified intervals and clamp lagging around the line between the weights to protect the coating during the laying operation.

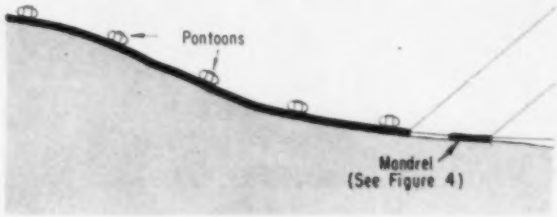


Pulling the line. The line is more shoved than pulled. To keep the nose of the pipe from burying into the side of the ditch, we spot a tractor on the opposite shore and hook its wire rope to the pad-eye in the bull-plug on the end of the pipe. Next, we pick the pipe section up with three side-boom tractors and simply walk it into the water. Once in water the pipe loses a good portion of its weight, making (in this case) an easier pull as the launching progresses. We backfill the approaches (which are of gentle slope) and let the center section await backfill by the river.

CASE HISTORY: CROSSING THE STRAITS OF MACKINAC

The Straits of Mackinac is about four miles wide and 250 ft deep in places at its narrowest point where Lakehead Pipe Line Company installed two 20-in. lines in the summer of 1953. The straits is by no means a river, but it is a flowing body of water, and the techniques used in constructing this crossing have been used a number of times since to cross actual rivers.

The methods used on this crossing were similar to those Transcontinental Gas Pipe Line Corporation devised to cross the Narrows in New York harbor at an earlier date. Merritt-Chapman & Scott was the contractor for the job; and Collins Construction Company of Port Lavaca, Texas, supplied most of the equipment used on the job. The method has since been used by Tennessee Gas Transmission Company to put in several Mississippi River crossings.



Overall plan. The ditch was dredged out to the 65-ft contour, and 2-in. pulling cable was carefully laid across the straits. Pipe was welded up in 2500-ft lengths on shore, and each of these sections was coated, wrapped, and fitted with lagging on the bottom to protect the coating.

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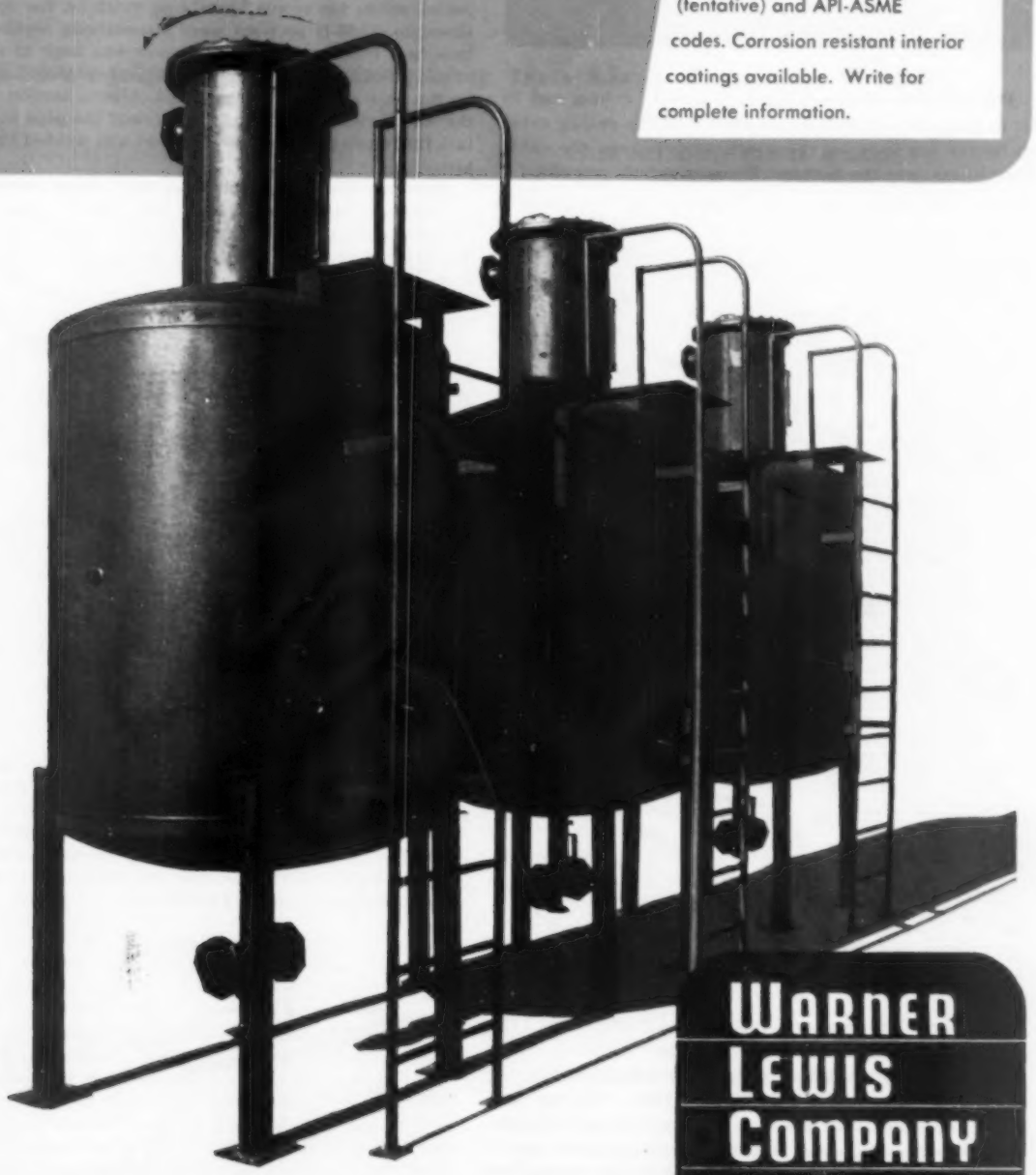

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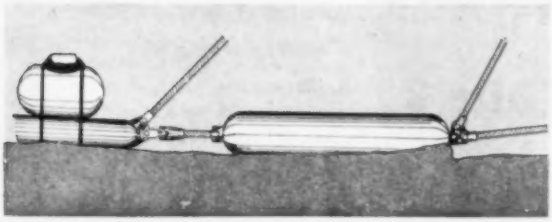
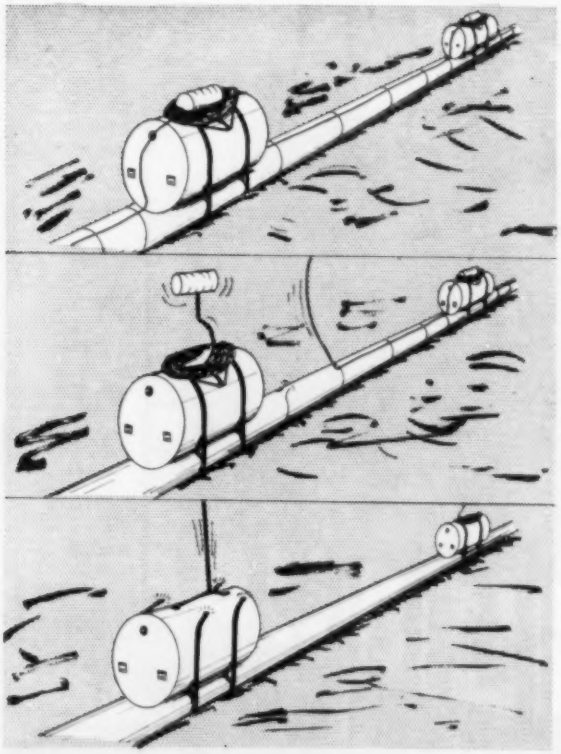
Pontoons were added every 80 ft so the pipe entered the water weighing 2¾ lb per ft. After the wooden lagging became water logged, the weight climbed to about 6 lb per ft.

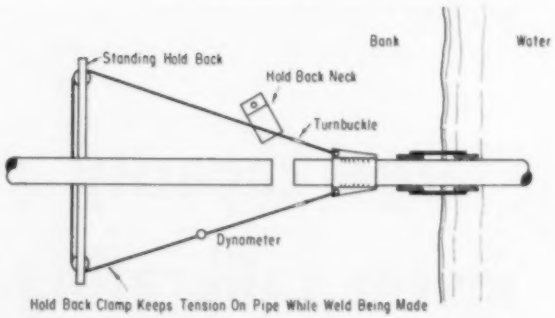
Once the pull started, each line was pulled across in about 65 hours.



Pulling cable. Mandrels made of pipe 11 ft long and 36 in. in diam were spaced every 2500 ft in the pulling cable to lighten the load on the winch, and to keep the cable from biting into the bottom. These mandrels smoothed a path for the pipe.



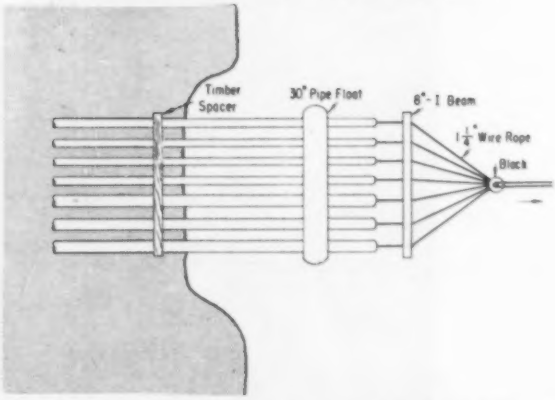
Pontoons. The pontoons, which had a floatation of 1700 lb, were banded to the pipe with steel straps. A cutter was fitted into the bands and attached to a manila tag line, which was attached to a small buoy. The tag line, buoy, and cutter were lashed to the pontoons, and the lashings were above an under running cable that ran the length of the crossing. This permitted the crew to free the tag line and buoy by tugging on the cable, and when the buoy floated to the surface the rope was pulled, and the cutters released the pontoon from the pipeline.



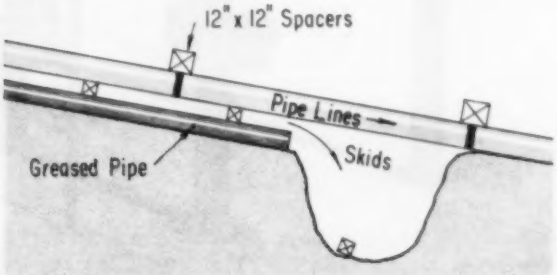
How the pipeline was kept in tension. The pipe was pulled across the straits by a large winch on the opposite shore, as 2500-ft sections were successively welded and launched. But the pipe in the water was kept in tension at all times. A hold-back winch kept a 12,000-lb tension on the pipe as it was pulled ahead. After a section was in the water, clamps were snubbed around the pipe to maintain this tension while a new section was welded onto the last.

Pipe was filled with water from the deepest point. Once the line was in place, a greased 4-in. pipe was run to the deepest point, and the line was filled with water from the low point outward. This allowed the line to take its slack from shore.

ACTUAL CASE: PULLING 7 LINES AT ONCE ACROSS A 2500-FT WIDE CHANNEL



Three 12-in. and four 8-in. concrete-coated pipelines were pulled simultaneously across the 2500-ft wide, 40-ft deep Houston Ship Channel near Baytown, Texas, in the fall of 1953. There were several different owners of the lines, but the entire project was engineered and designed by Shell Pipe Line Corporation. This technique shaved the cost of the project some $600,000.



The launchway. The pipe was welded up in 800-ft sections for launching. The sections were coated and moved

onto 12 x 12 oak timbers spaced every 80 ft or so along a launchway of three lengths of 8-in. pipe resting on the ground. This pipe was kept greased, so the timbers would slide as the pipe was pulled into the water. At the end of the greased pipe near the water's edge, the pipeliners dug a ditch, which allowed the timbers to drop from beneath the pipe.

Spacers. The seven lines were clamped together with timber spacers every 100 ft, and after the lines were in place divers removed them prior to backfill.

Weight of the line. The seven concrete-coated lines weighed a total of 800 lb per ft, or 2,000,000 lb total.

First pull. A 1¼-in. pulling cable from the opposite shore was attached to the pulling bridle, and, with four tractors on the launchway pushing, the first 800-ft section entered the water.

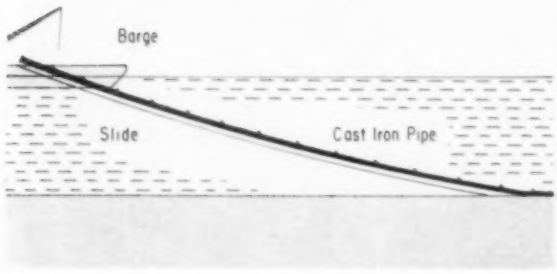
Second pull. There was a two-day time lapse between pulls, while the second section of pipe was welded onto the first, X-rayed, clamped, etc. This allowed considerable silting, and more force was required for the second pull. A three-sheave block was attached to the pulling end of the pipe and three barges were used to buoy the pipe during the pull.

Third pull. Two tractors were moved across the channel to augment the pull of the 200-ton winch and, with six tractors pushing, the last section was launched and moved into place.

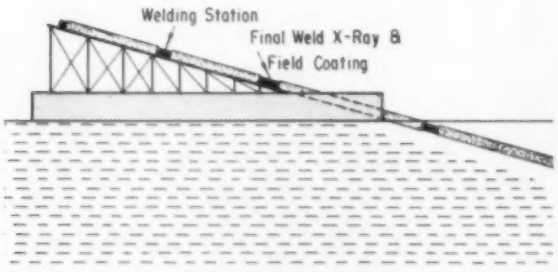
Backfill. This was left to natural silting.

Stovepiping or Ramping the Line from a Barge

EARLY CAST IRON LINES LAID THIS WAY



OIL & GAS LINES LAID LIKE THIS TODAY



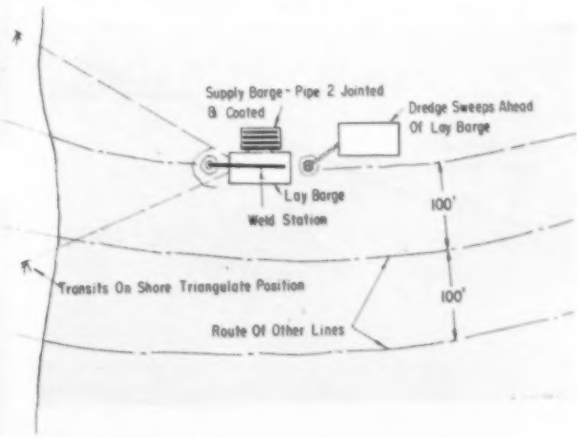
This method originated with cast-iron lines laid across some of our very deep and swift streams. Joints of bell and spigot cast-iron pipe were added successively joint by joint from the head of an inclined trough on a barge. This trough slanted the pipe down into the water and curved it onto the bottom as the barge moved ahead joint length at a time. This practice is still followed—only today the cast-iron pipe is flanged at each joint.

Description of the method. As a rule, the steel pipe is double-jointed and concrete-coated on shore, hauled out to the ramp barge where these joints are added successively to the line. After each weld, the weld area is coated, X-rayed, etc. and the barge is moved ahead until there is room for the next joint on the ramp. Depending on the depth, it is sometimes necessary to support the pipe after it leaves the lay barge, to prevent severe bends that may crack the coating or possibly damage the pipe.

This is a common method of laying crossings. Nearly all of the lines across the Mississippi were laid by this means.

CASE HISTORY: TRIPLE MISSISSIPPI RIVER CROSSING

Tennessee Gas Transmission Company laid three 18-in. crossings of 1⅛-in. wall pipe across the Mississippi near Lake Providence, Louisiana. The lines were laid in a 200-ft wide ditch 100 ft apart. They were laid one at a time in parallel downstream loops.

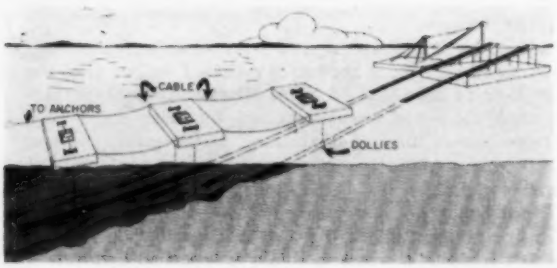


Ditching. Two eight-yard draglines moved several hundred thousand cubic yards of sand at the waters edge preparing the approaches. The depth of the cut for the crossing varied from 80 ft deep at the banks to zero feet at the center of the main channel. This required moving 3,000,000 cu yd of dirt by dredge.

Pipe laying. The 18-in. heavy wall seamless pipe was double-jointed, cleaned, primed, and double-wrapped in the usual manner. Welding required about four hours per weld using two welders. The 80-ft sections of pipe were transported to the lay barge in the river. The latter was 175 ft long with a 60-ft beam. The average laying time was about 6 hours per 80-ft length.

CASE HISTORY: TRUNKLINE'S MISSISSIPPI RIVER CROSSING

Trunkline Gas Company laid two 24-in. parallel Mississippi River crossings about 20 miles below Greenville, Mississippi, in 1954. The contractor, Missouri Valley Dredging Company, laid the two lines simultaneously, using two ramp barges — spaced apart so the pipe supply barge could moor between them. The barges were tied together

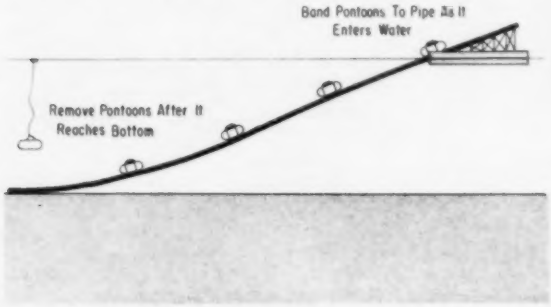


with structural steel to make a single unit, and were operated in conjunction with a derrick barge anchored to the assembly.

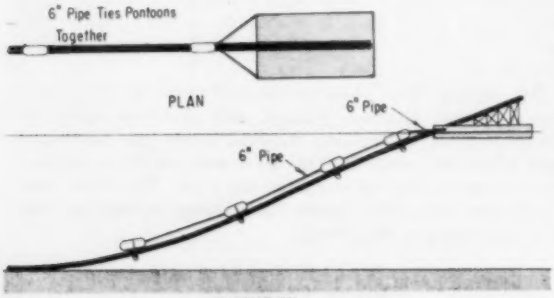
Lowering the barges. The most noteworthy feature of this job was the lowering-in barges that supported the spans of pipe from the ramp barge to the ditch bottom. Their purpose was to minimize the bending radius. As the pipe rolled down the ramp barge, each line was supported at four points by rubber-tired dollies hanging from the lowering-in barges. Each of the cables hanging from the barges ran through a well in the barge to a winch drum.

OTHER WAYS OF SUPPORTING PIPE BETWEEN THE RAMP BARGE AND THE BOTTOM OF THE DITCH

As shown in accompanying illustrations there are other ways to support pipe between the ramp barge and the bottom of the ditch. One of these ways has never been tried. However, there's little doubt that it will work.



In one instance, the pipe is buoyed at calculated intervals to give it the proper curvature. Using pontoons similar to those used on the Straits of Mackinac crossing, the curvature of the pipe can be controlled. After the pipe reaches bottom the pontoons can be removed. This method is being used in offshore construction at this time.



Another way to support the pipe is to space pontoon supported dollies along the pipe so that it receives support as it goes into the ditch. As the ramp barge progresses, the pontoons and dollies move forward. This method would save boat crews and banding material where it is applicable.

FLOATING THE LINE INTO POSITION AND SINKING IT

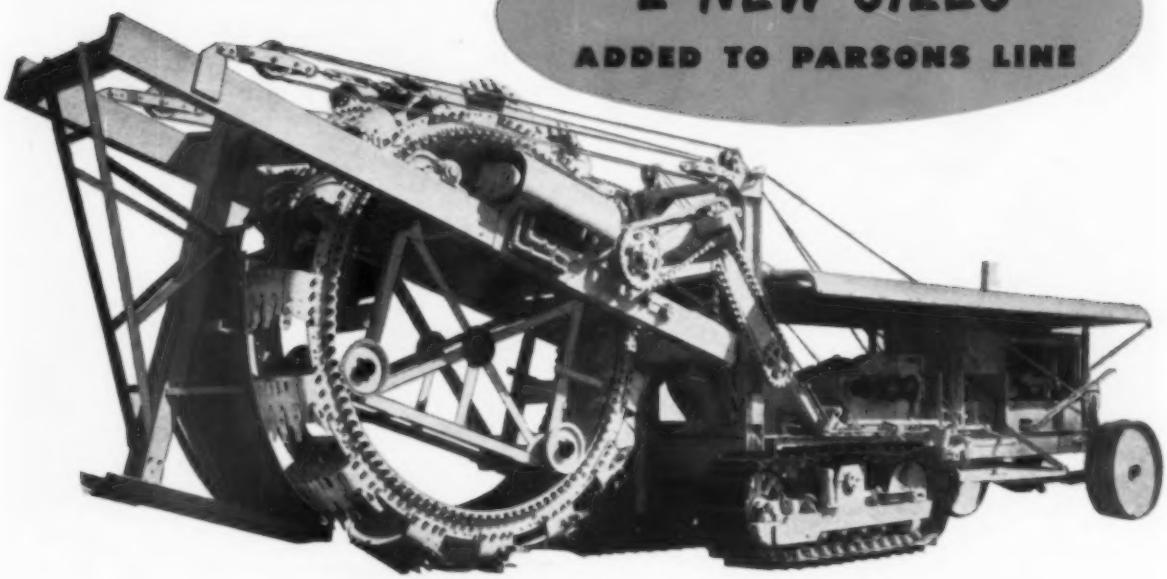
This is one of the most popular methods of constructing underwater lines. It has several advantages: (1) Less weight has to be handled, and (2) minimum equipment can be used. The method is especially applicable for crude and products lines because of their light weight. However, many gas lines — even some of the very heaviest — have been laid by this method.

CASE HISTORY: TRANSCO'S ARTHUR KILL CROSSING

The Arthur Kill is a deep tidal stream separating New Jersey and Staten Island. The contours of its bottom are sharp and angular, making it virtually impossible to run a smooth curving line beneath it. A high density muck courses down the stream requiring considerable negative buoyancy to keep a crossing on the bottom of the ditch until it has healed.

2 NEW SIZES

ADDED TO PARSONS LINE



BIG-INCH 520 .... AND MIDDLE-INCH 420

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Big-Inch model 520 opens up to 28 lineal feet of trench per minute, depending on depth, width requirements, and working conditions. It digs from 40 to 52 inches wide — and as deep as 8½ feet.

With Parsons Middle-Inch 420 Trenchliner, you get digging speeds up to 44 lineal feet per minute — trench widths from 31 to 46 inches, and depths to 7½ feet.

Originally developed by C-R-C, and now built by Parsons, these two big-wheel ditchers bring you the combined engineering know-how and services of both firms. It will pay you to get more information on these heavy-duty Inchers.

Other Trenchliners in the Parsons line include smaller wheel-types (new 170 shown at right) — and ladder-types on rubber or crawlers, in a complete selection of sizes to serve all your needs. Contact your Parsons distributor or write for literature *today*.

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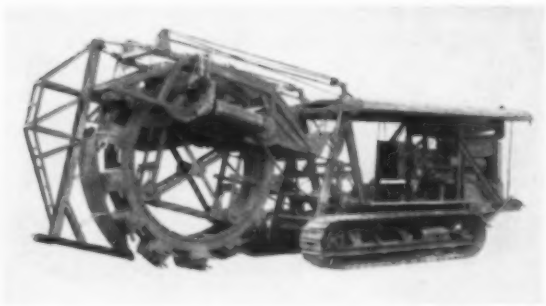
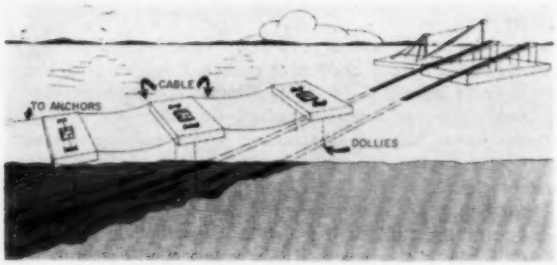


Another recent addition to Parsons line is the new 170 — a medium-size ditcher with extra-wide wheel frame. It digs 20 to 32 inches wide, at depths to 5¾ feet — has hydraulic wheel-hoist on power-tilt mast. Conveyor is hydraulically driven. Belt speeds are completely independent of digging wheel speeds.

TRENCHLINERS® for PIPELINERS



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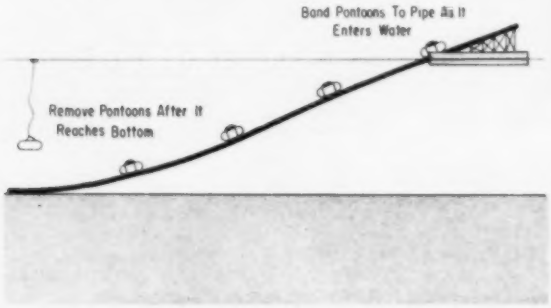

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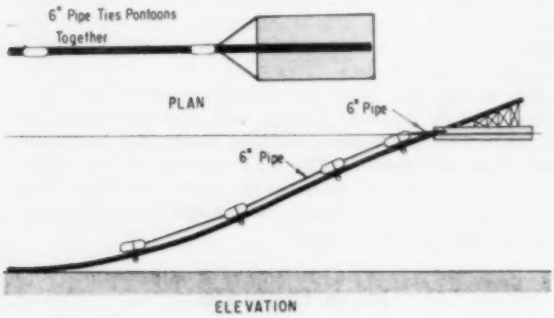

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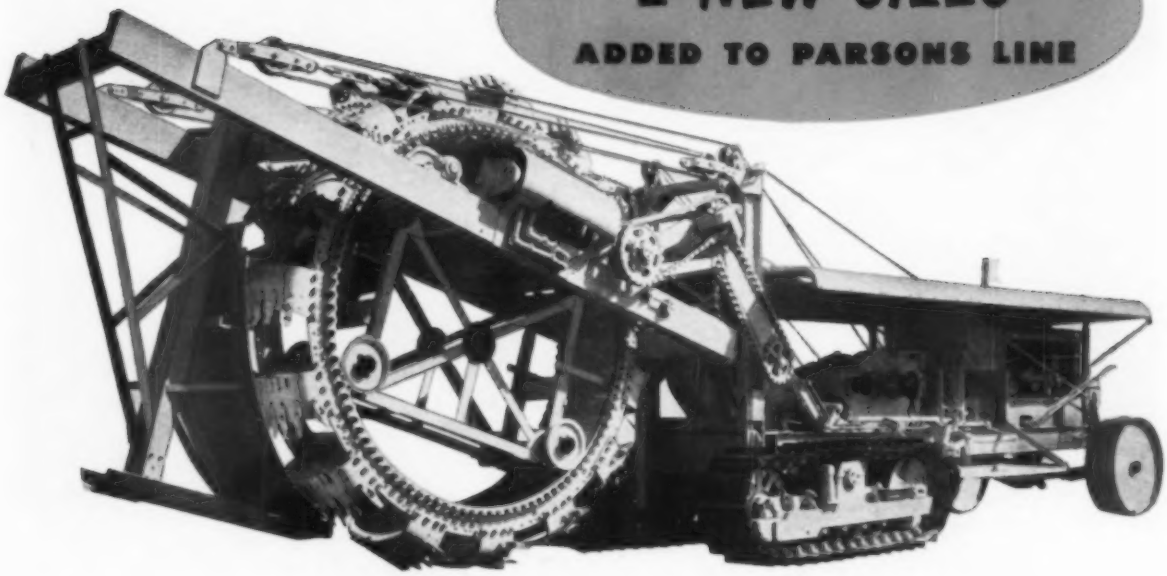

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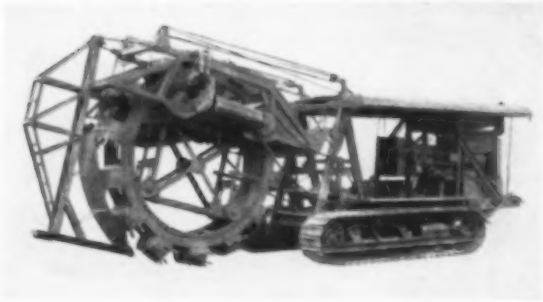

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TRENCHLINERS® for PIPELINERS

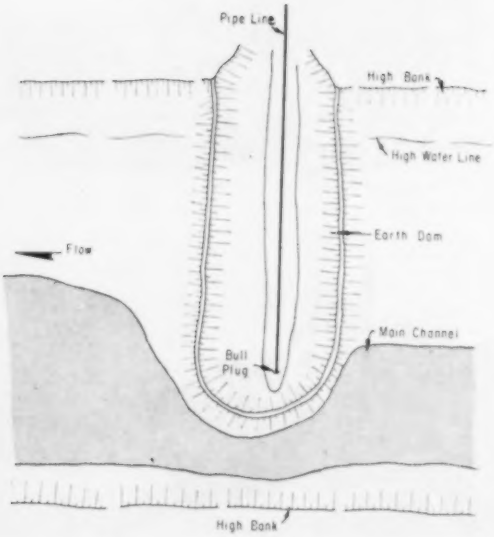
P785REV.

Transcontinental Gas Pipe Line Corporation's 26-in. crossing is both heavy and angular. Pipeliners welded it up on shore, attached pontoons to it as shown, and floated it above the ditch on its side. Holding the ends in position, the crew released certain ones of the pontoons, and the crossing rotated 90 deg to a vertical position. Then additional pontoons were released, and it sank to bottom. Tie-ins were made next and then all the pontoons were released, and the crossing assumed its permanent place on bottom of the ditch.

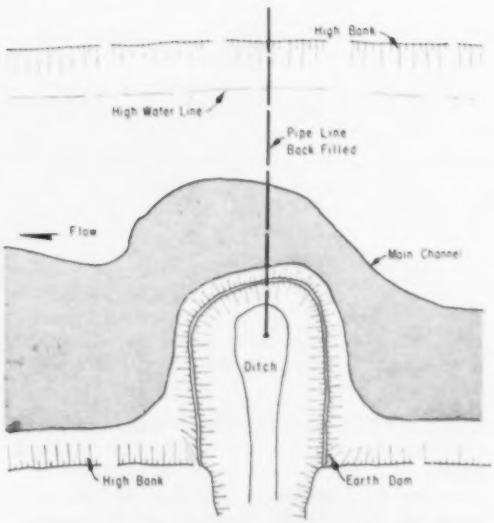
CASE HISTORY: SMALL CROSSING SUNK WITH WATER THEN WEIGHTED

By elevating the ends of a crossing after it has been floated into place and filling it with water to sink it, pipeliners often can save considerable construction costs. After the line has been sunk, concrete half weights can be placed on the line to give it the necessary negative buoyancy.

Diverting Stream and Using Dry Land Methods



This method has been used recently by Texas Eastern Transmission Corporation to span the Rio Grande and by El Paso Natural Gas Company in crossing the San Juan River in the Four Corners area. It also has been used by various pipeline companies to cross the Canadian, Republican, Arkansas, Platte, and Red Rivers, to mention a few others.



Description of the method. Simplified: Move the river to one side and lay pipe under the other (dry) side. Then divert the river over the line just laid and construct the other side of the crossing.

There are innumerable variations of this technique, depending on the depth of the river, the nature of its bed, and the materials at hand.

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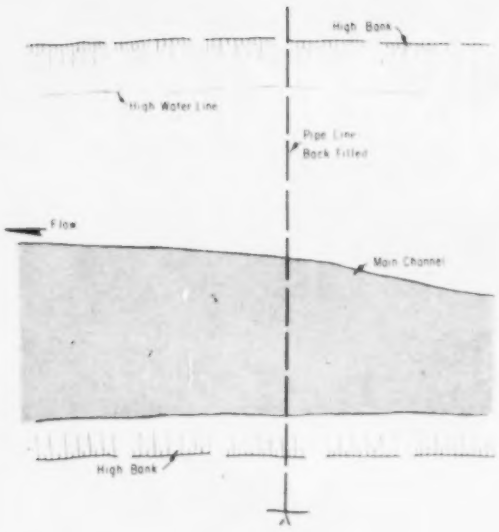
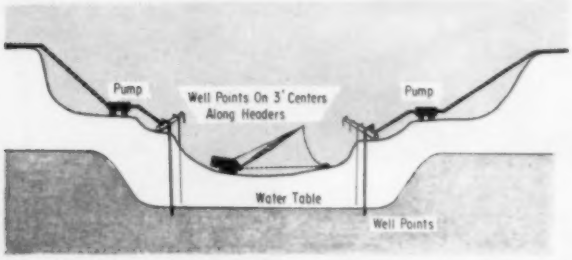


Where it is applicable. Primarily, this method has been used to lay deep, long crossings under wide river beds through which the stream meanders frequently. In most instances the river bed will be composed largely of sand and silt.

How to divert the river. This can be done by constructing a temporary earthen dam with bulldozers or draglines. Where it is economical the same result can be achieved by using sand bags.

Problems. The number one problem in almost every case is underground water, which will fill the ditches on the dry side almost as fast as they are excavated. Also, if the water volume is high, it is sometimes difficult to maintain the cofferdams against stream erosion.

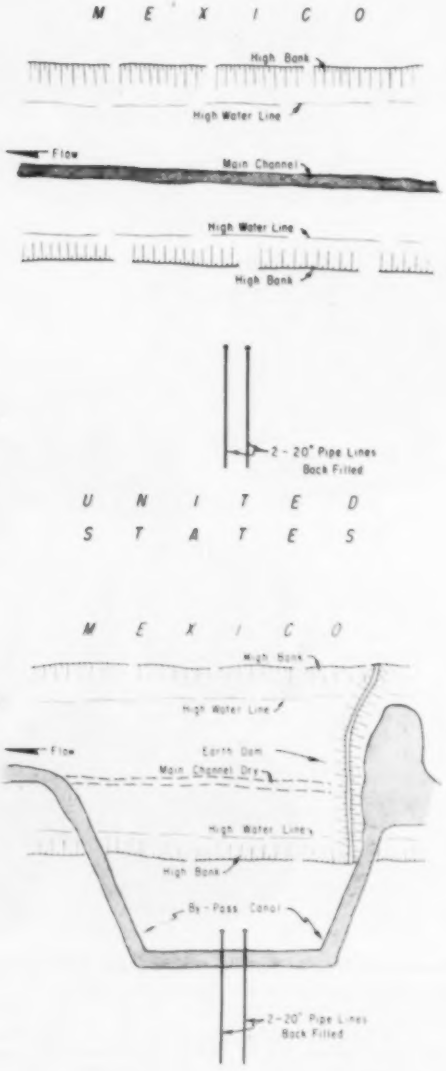


Solution. The key to this problem is the well point, the kind used in shallow water wells. By installing a system of such wells, water can be removed as rapidly as it can migrate from the river through the sand. This system can be expanded in tiers as the excavation goes lower.

CASE HISTORY: RIO GRANDE CROSSING

Most people know that the Rio Grande forms the boundary line between Mexico and Texas, but few realize just how often that "boundary line" changes its course. Operating in a river bed some 2000 ft wide, the stream may dwindle to a mere few feet in width and no deeper than the top of your shoes. At other times it becomes a raging torrent eating away at its sandy silt banks. Because of these vagaries, Texas Eastern Transmission Company decided to lay to grade some 3500 ft of its twin 20-in. lines that will bring Mexican gas into the U. S. The lines are 42 ft deep back in the banks and 20 ft below the river bed. This is 8 to 10 ft below any known scouring.

To accomplish this task, Texas Eastern had to move



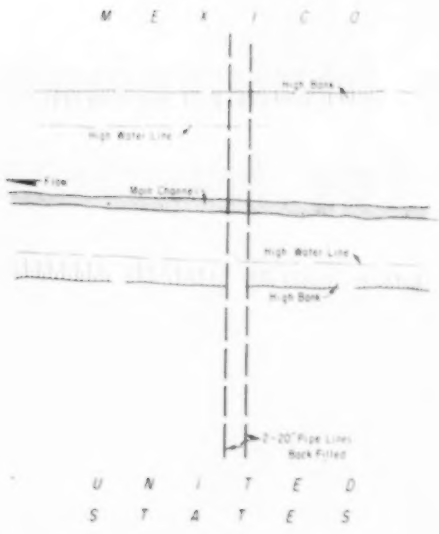
nearly 1,000,000 cu yd of dirt. The first step in the job was to lay the U. S. approaches, including a 700-ft section of lines, which were backfilled. Next, a diversion canal was cut upstream from the crossing site. A diversion dam was laid across the river, and the water diverted around the crossing. Dry land excavation was begun.

When excavation reached the water table—roughly the elevation of the water in the river—well points were installed. This enabled pipeliners to continue work well below the level of the river.

After the remainder of the crossing was completed, it was tied-in to the 700-ft section beneath the diversion canal, and the latter was backfilled.

Unusual River Crossing Construction Practices

MISSISSIPPI CROSSING



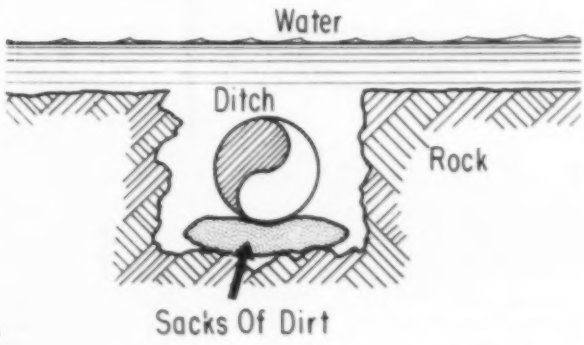
One of the most unusual crossings of the Mississippi was laid in 1953 by Southern Natural Gas Company. Four 10-in. lines were laid in parallel curves upstream. The lines were tied in at the banks, and laid in the bottom of the river proper. The idea behind this practice (which seems to have been highly successful—after all a good Mississippi crossing is one that hasn't failed *yet!*) was to provide slack that could follow the meanderings and scours of the bottom. Also, the lines are inexpensive, and if one fails, the system is not greatly impaired.

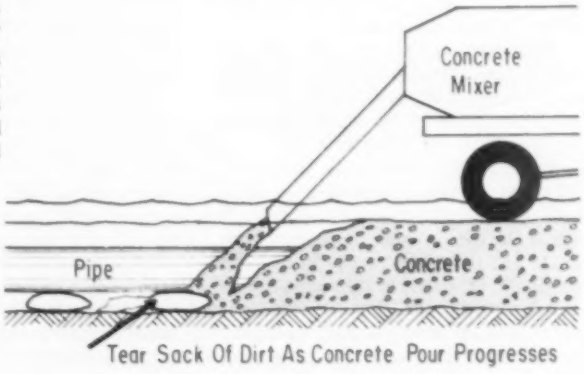
CONCRETED RIVER CROSSINGS

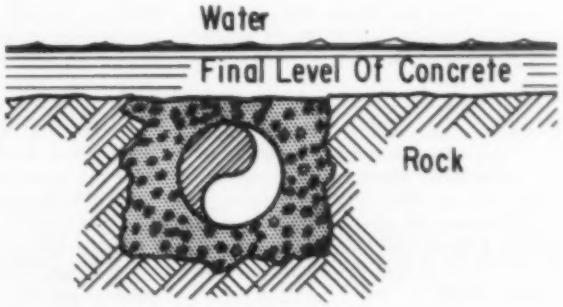
Several shallow rivers with rock bottoms were sealed in a below grade concrete envelope by Shell Pipe Line Corporation who engineered and designed the Rancho system. Here's the way it was done:

Ditches were blasted through the rock and because the stream was shallow the coated line was laid on bags filled with dirt along the bottom of the ditch. After it had been tested it was concreted in place.

Sacks of dirt were ripped and the dirt was dissolved in the water just ahead of the concrete mixer. The concrete was poured in two lifts. The first one covered the bottom third of the pipe. Then the concrete mixer filled the ditch completely full and flush with the bottom of the river.







CONCLUSION

If you're a pipeliner, chances are you can cite many jobs where the practices given here were varied widely. If you were observant and visited many jobs this summer you probably saw many such variations, and this trend will continue, until someone finds the perfect way to lay a pipeline river crossing.

Here's how Pacific Lighting Gas Supply developed a workable program of...

Preventive Maintenance For Magnetos

James T. Carter, Jr.
Pacific Lighting Gas Supply Company
Los Angeles, California

PACIFIC LIGHTING GAS SUPPLY COMPANY operates nine compressor stations from Goleta to Huntington Beach. Three are in the Western division — Goleta, Ventura and Somis. The remaining six — Whittier, Santa Fe Springs, Brea, Signal Hill, Dominguez, and Huntington Beach —are in the Southern division, located in Los Angeles and Orange counties.

All main compressor units are gas fueled spark ignition engines. Except for 10 units at Ventura, equipped with magnetos, all main units use magnetos for the spark ignition source.

There are 132 main units with a total rated 36,275 hp installed in these nine stations. Of the main units, 100 are of the two-cylinder, horizontal type in the 165 to 200-hp range. Many were originally equipped with oscillating or trip lever operated, high tension magnetos and, for the most part, have been converted to the use of rotary high tension magnetos. The auxiliary pumps, air compressors, generators, etc., are also driven by gas fueled engines using magneto ignition. There are 94 auxiliary power units with a total rated horse power of 4301.

Until the establishment of the magneto repair shop five years ago, servicing rotary magnetos consisted of an occasional check of, or replacement of, the points. When service or replacement of the points did not suffice to keep the magneto operating, it was sent to one of several outside service shops.

Salvage Aids Repair

With increasing age of the oscillating magnetos it became more and more difficult to obtain replacement parts. By salvaging parts from junked magnetos for use in repairing other obsolete magnetos, the service life of some of these magnetos were appreciably extended. This salvage work was carried on at the stations by station personnel. At one location, one of the men doing salvage and service work had an aptitude for and an exceptional interest in magneto repairs. In 1949, this mechanic, at Huntington Beach station, was permitted to perform all maintenance and repair work on all magnetos used at that location. Use of the outside service shop was discontinued.

With existing station equipment and a few inexpensive parts, a simple magneto test stand was assembled. Data for magneto service were gathered from various locations, principally the magneto distributors and manufacturers. During approximately two years of experimenting and keeping accurate records of repair data as related to running time, the basic program for preventive maintenance at this station became evident.

The next step was to establish that magneto operating conditions at the various stations were uniform enough to permit comparisons. The final answer in the selection of ignition system components has not necessarily been reached. Through trial and error experimentation on a system-wide basis, those items and procedures that have demonstrated their ability to minimize difficulties and failures have been adopted.

Maintenance mechanics are aware of the importance of maintaining the entire ignition system; spark plugs, high and low tension leads and transformer coils, in the best possible condition. Our equipment is of relatively few types. The main units are either older low speed (180 to 200-rpm) horizontals; or more modern, higher speed (300 to 330-rpm) angle types. Auxiliary power units are, generally, various models of one manufacturer's engines. Thus representative models of both main and auxiliary equipment are installed at Huntington Beach station.

Preventive Maintenance Program

Because of the similarity of equipment and uniformity of service conditions, the preventive maintenance program developed at Huntington Beach station could have been used at all stations in 1951. Data on annual costs of magneto repairs, including such minor adjustments as were performed by station personnel, were not readily available. In 1951, at the more active stations, use of older magnetos had almost been eliminated.

Comparison of 1951 and later costs with pre-1951 costs might have given a distorted picture because of comparing modern rotary magnetos with obsolete types. Therefore, the preventive maintenance program at Huntington Beach station was used, and previous practices at the others was continued, accumulating data for comparable magneto equipment.

During the next three years, minor revisions in the preventive program were made, mainly in extending the period between servicing. The present magneto maintenance program establishes four separate service conditions which in turn establish the repair periods for each magneto. The repair periods are based on actual operating time. For convenience, calendar periods are used in maintenance schedules. However, units are seldom shut down for the sole purpose of servicing the magneto and actual service occurs at approximately the periods shown in the schedule.

Fig. 1 shows the service conditions that warrant different inspection and maintenance periods, and shows the periods at which minor and major overhaul jobs are performed.

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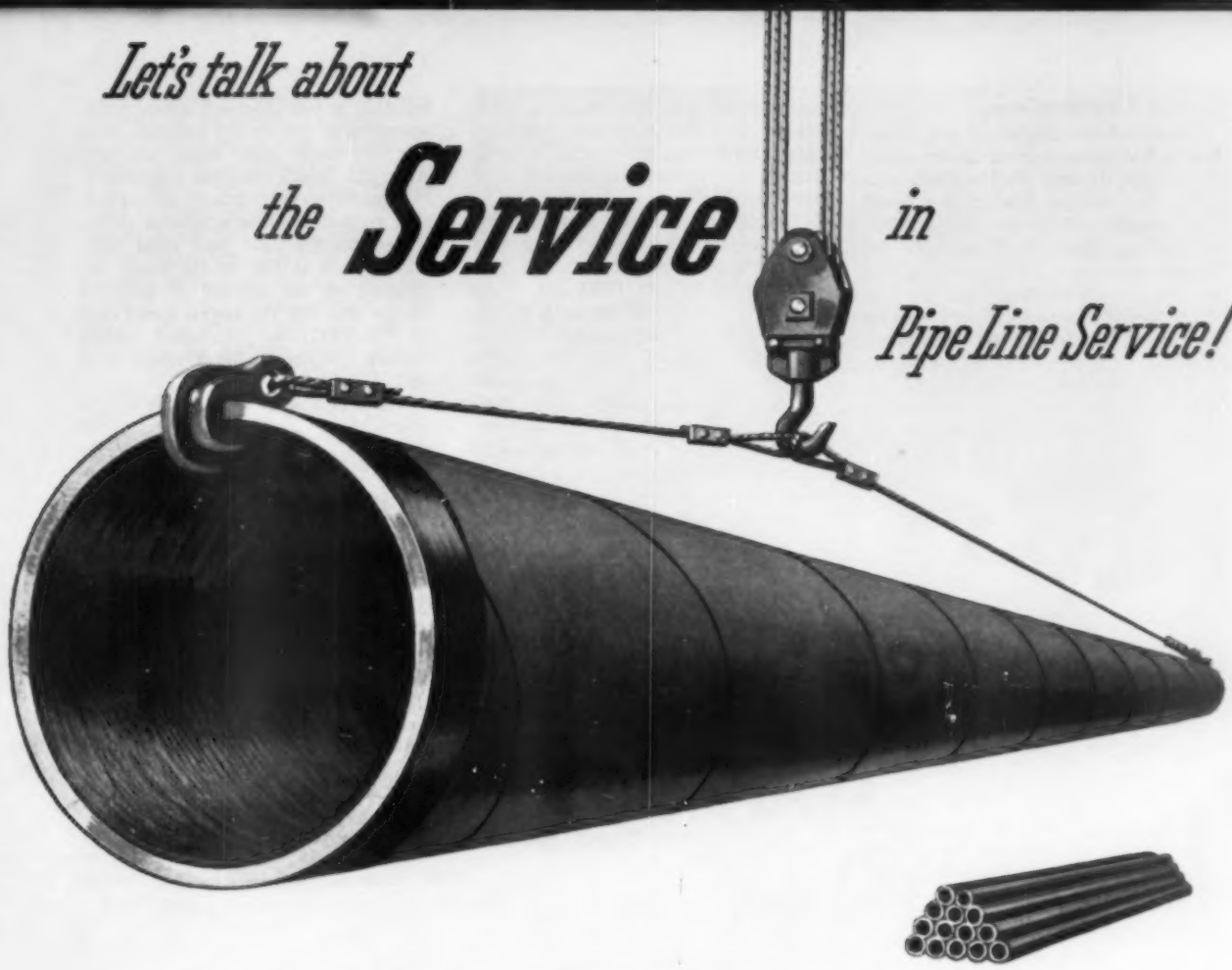

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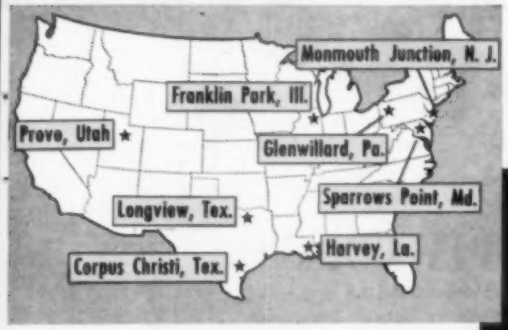

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Service Classifications

These service conditions are classified by relative severity of the service as Class I, II, III, and IV. The chart indicates the items upon which are based the severity-of-service classification. While these classifications are sufficient for some purposes, different equipment or the same equipment operating at other speeds or load conditions may require different frequency of maintenance.

The most severe service, called Class I here, is for a high tension magneto operating at or above 1800 magneto rotor rpm. As limited by the type of equipment in service, all magnetos in this service are high tension, carbon brush distributor type, installed on automative type four cycle engines. Typical of this service is an American Bosch MJA magneto on a six-cylinder engine that operates at 1200-rpm or above.

FIG. 1.

Service class	Maintenance period: Minor overhaul	Maintenance period: Major overhaul
Class I High Tension 1800 rpm plus	1 month	1 year
Class II High Tension 800 to 1700 rpm	2 months	1 year
Class III High Tension - Less than 800 rpm	1 year	3 years
Class IV Low Tension 600 to 1000 rpm	None	1 year

Following this same pattern Class II is less severe because of lower magneto rpm. The magneto speeds here range from 800 to 1700-rpm. Typical of this service are high tension magnetos on six-cylinder engines operating at 800 to 1100-rpm, or on four-cylinder engines operating at 800 to 1200-rpm.

Class III service covers those magnetos operating at 800-rpm or less. Included in this class are approximately as many magnetos as the other two high tension service classes combined. Typically, this service covers magnetos installed in our older horizontal units, operating at 330 to 400 magneto rpm. For the most part, these are now American Bosch MJ type magnetos.

Class IV service includes all low tension magnetos. These magnetos are installed on the new type main units and operate at 600 to 1000-rpm, depending on the number of cylinders on the unit and the engine speed (300 to 330-rpm). As mentioned earlier, battery ignition on the Ventura main units is being replaced.

These new magnetos operate at 360-rpm and are all of the low tension type. They will be treated the same as the existing higher speed low tension units unless actual operation shows that the service period can be lengthened. All

FIG. 2. Magneto Information.

Date _____ Mag. No. _____
New Magneto Information
Station No. _____ PLGS Co. No. _____ Type _____ Model _____
Repair Record
Date Repaired _____ By _____
Materials Used: Cost: $
_____
_____
_____
_____
Total cost of materials used
Labor: _____ Hr at $ _____ per hour
TOTAL COST TO REPAIR MAGNETO
Transfer Record
Date of Transfer _____ From _____ To _____
Recorded _____ Signed _____
(Form 71)

FIG. 3. Pacific Lighting Gas Supply Company Magneto Repair Record.

Make _____ Model No. and Style _____ Factory No. _____ Mag. No. _____

Date repaired	Cost: Material	Cost: Labor	Repaired by	Remarks	Date of transfer	Transfer from	Transfer to

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except four of these low tension magnetos are of the Bendix LA type.

As a sub-class in Class I, also included are those magnetos that normally would fall into Class II but which, because of periods of inactivity, require more frequent attention. This occurs where there is 100 per cent standby, as is usual for air compressors and some pumping services. With 100 per cent standby, the units operate alternately for periods of one month each.

After one month of running time, sufficient carbon dust and dirt has accumulated in the magneto so that moisture may accumulate and cause the magneto to fail to perform, or may cause hard starting. Since these units are normally checked and the oil is changed at the end of the month's running time, only a little more time is required to install a reconditioned magneto. Assuring easier starting in case of emergency needs for the unit is well worth while.

Types of Overhauls

Repairs and maintenance performed fall into only two categories. The most frequent maintenance, or minor overhaul, requires only a minimum of dismantling of the magneto, unless the magneto condition warrants further inspection and repair.

Maintenance performed on the second, or major overhaul, consists of complete dismantling of the magneto in addition to performing the maintenance accomplished on the minor overhaul. A list of the inspections and adjustments made on Minor and Major Overhaul includes the following items:

MINOR OVERHAUL

1. Clean the exterior.
2. Remove the distributor plate and points.
3. Clean the interior made accessible by removing the distributor plate and points.
4. Clean and inspect the brushes and rotor.
5. Dress the points and inspect the cam for wear.
6. Check the condenser with instrument.
7. Reassemble the magneto, setting point gap and lubricating the cam wick and cam.
8. Remove the impulse coupling; clean, inspect and reassemble.
9. Run magneto on test stand checking:
   a. Primary output.
   a. Edge gap distance setting.
   c. High tension output.
   d. Impulse operation.

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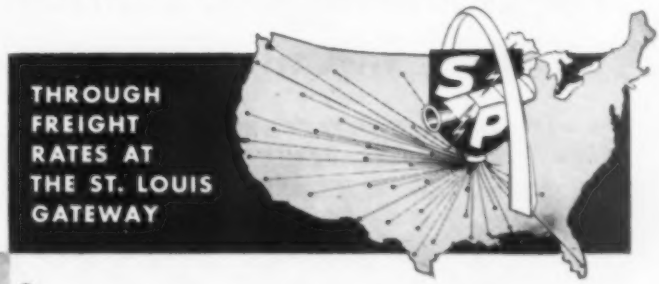

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FIG. 4. Magneto Repair Record.

Make _____ Type _____ Cyls. _____ Service _____ Rotation _____ RPM _____ Station _____

Date	Exterior	Interior	Distributor plate	Breaker points	Condenser	Coil	Impulse	Rotor	Bearings	Other repair	Test pressure	Repair time	Remarks

MAJOR OVERHAUL

1. Clean the magneto exterior.
2. Install the magneto on the test stand and check:
   a. Impulse operation.
   b. Output of primary and secondary.
3. Completely disassemble and clean the magneto including removal of the magnet rotor and impulse coupling.
4. Inspect bearings.
5. Test coil for opens or shorts.
6. Test condenser.
7. If primary output was low on test run and coil is all right, recharge the magnets.
8. Inspect the distributor rotor and resurface or replace as required.
9. Repack the bearings and reassemble the magneto using new or reconditioned parts as needed.
10. Install the magneto on the test stand and recheck the output.
11. If condition of the exterior indicates the need, repaint the exterior (lacquer).

Low tension magnetos require much less maintenance than high tension magnetos. In fact, experience has shown that dressing the primary points and distributor points would be sufficient for annual servicing. However, in order to reach the distributor points, the magneto must be partially disassembled. Therefore, each overhaul of the low tension magnetos is comparable to the major overhaul on high tension magnetos.

How PM Program Works

This program has been developing since 1949. Starting in 1951, accurate records were kept of all magneto maintenance expense by station and magneto. One point uncovered during preparation of this article indicates that for stations using outside service shops, all station labor on magnetos may not have been included in the reported cost data. This would cause the previous maintenance program to look better cost-wise than it now does.

Since each station was charged with the responsibility for determining when maintenance was required, no central control was imposed on the frequency of service. Costs of repairs, both outside and company performed, were reported to the operating department office on a form developed for this purpose. This is shown in Fig. 2.

The form has two additional uses: *first*, reporting to the office the type and installation number when new magnetos are placed in service; and *second*, reporting to the office when magnetos are transferred between stations.

Fig. 3 shows the master record card maintained in the office for each mag-

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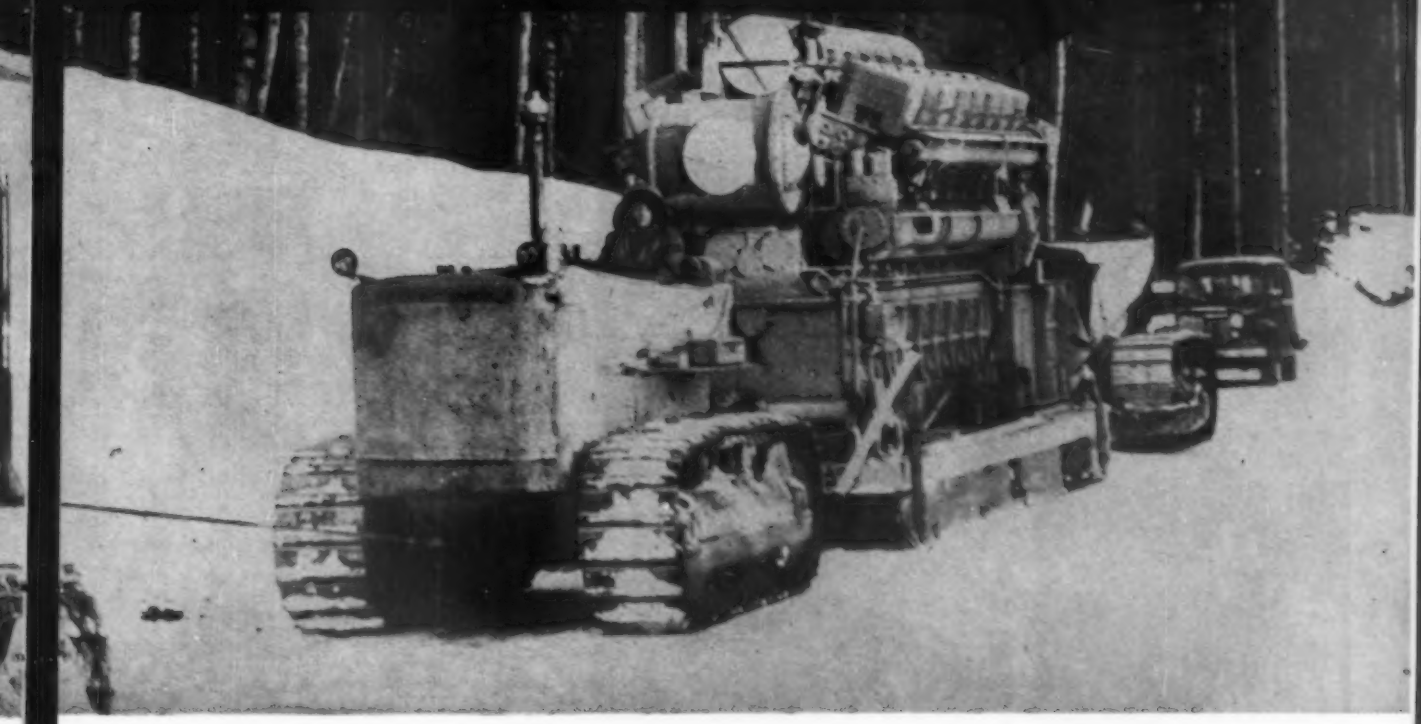

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neto. On it are recorded the costs of repairs as they occur and are reported to the office.

Fig. 4 shows the master card maintained by the serviceman for each magneto. At the time of inspection or repair he enters parts used and conditions noted on overhauling the magneto.

Costs

A compilation of the costs incurred over the past three years is shown in Fig. 5. The costs for Huntington Beach station are for preventive maintenance, while the other three stations used outside service without preventive maintenance.

Since major overhaul occurs on a running time basis and the load factor at Huntington Beach is 68 to 74 per cent, each calendar year may not include an equal number of such major overhaul jobs. This is the base because a number of repair jobs, and thus repair costs, fluctuate widely from year to year on a calendar year basis. Therefore, total costs for the three year period were used for comparison.

This compilation covers only the modern rotary magnetos since the few older type magnetos show costs of maintenance out of proportion to their number and actual service. These older magnetos have been retained in service because they are installed on equipment which is in standby condition. Until such time as continuous operation of this equipment justifies replacement, these old magnetos will be retained as long as they can be made to function.

Note in Fig. 5, that the Class III service covers 50 operating units, while Classes I and II combined cover 38 units. These data are based on the cost of magneto repairs required to accumulate the unit operating hours shown under "Total Operating Hours." Thus the 50 Class III service units require approximately 55 magnetos to provide sufficient spares to permit removing magnetos for periodic service in the repair shop. About 10 per cent spare magnetos are provided for the Class I and Class II service also.

The data indicate that no magneto repair cost savings are made for Class I and II service. Our cost with or without preventive maintenance was approximately 2.5 mills per operating hour. Brea costs were lower because all four units there are Class II service while the other stations have approximately 20 per cent Class I service.

Average cost per repair with preventive maintenance (Huntington Beach) of $3.65 is less than the standard labor charge made by outside magneto shops. Our experience has been that most

Working on the distribution system for the Trans-Canada natural gas pipeline, this new Barber-Greene Model 774 Ditcher cuts through clay frozen to a depth of five feet at temperatures around 26° below zero.

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Fig 5

	Signal Hill	Brea	Ventura	Huntington Beach
CLASS I and II SERVICE (3 year period—1952 to 1954 inc.)				
Number of units	7	4	11	16
Total operating hours	144,629	122,503	227,810	287,928
Load factor (Op. hrs. as % of possible)	78.6%	87.4%	79.8%	68.4%
Number of magneto repairs	16	17	45	186
Total cost of repairs	$350.90	$212.22	$552.80	$711.79
Average cost per repair	$21.90	$12.50	$12.25	$3.65
Cost per operating hour (mills.)	2.43	1.73	2.43	2.47
CLASS III SERVICE (3 year period—1952 to 1954 inc.)				
Number of units	16	8	0	26
Total operating hours	126,246	122,750	0	508,719
Load factor (Op. hrs. as % of possible)	30.0%	58.4%	0	74.4%
Number of magneto repairs	5	12	0	62
Total cost of repairs	$100.17	$117.40	0	$226.57
Average cost per repair	$20.03	$9.79	0	$3.66
Cost per operating hour (mills.)	.793	.956	0	.446

shops make a flat charge for labor that amounts to approximately $6.00. Thus, preventive maintenance could not show any cost savings for our operations. The 186 repair jobs would have cost $1100 for labor only if performed by outside shops, or about 4 mills per hour against the station's 2.5 mills average cost.

The advantages of, and cost savings because of, uninterrupted service are sufficient to make preventive maintenance desirable for these two services. Continued accumulation of data may show a slight decline in preventive maintenance costs per operating hour due to spreading all major overhaul costs over a full 8760 hours per magneto for these Class I and Class II services. Some of these magnetos may not have accumulated a year's operation since the last overhaul.

For Class III service, the cost per operating hour with preventive maintenance is approximately one-half the cost without preventive maintenance — .446 mills per hour vs .8 to .9 mills.

The actual repair cost savings indicated for the 26 units in Class III service with preventive maintenance, approximates $210 for the three-year period covered. This indicates that $110 less could have been spent on the 24 units not covered by the program during this three-year period.

Projecting these figures into the future (.446 mills vs .874 mills) our current and probable load factors indicate that we should spend approximately $125 per year less by having the preventive maintenance program for the 50 slow speed magnetos in Class III service covered by this study.

For Class III service, the cost of preventive maintenance is about 60 per cent of the cost of repairs performed by outside shops for the stations not using preventive maintenance. Again, the cost of the preventive maintenance program, if repairs had been performed by outside shops, would have been about $375 for labor alone, or approximately 0.7 mills per hour. With the inclusion of replacement parts, the preventive program would have cost as much per hour as, or more than, the non-preventive program.

Since there were only 18 low tension magnetos in operation during the 1952-1954 period, and only one of these was covered by the preventive maintenance program, no valid cost comparisons can be made for the operations. In general, low tension ignition systems require much less maintenance than high tension systems. In addition to the advantages inherent in low tension systems for some applications, the basic design features of the low tension magnetos eliminate some causes of magneto failure.

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Reduction of Costs

The cost reduction goes hand in hand with elimination of unscheduled shutdowns of equipment due to magneto failures. Since 1950, occasions of magneto failures during operation for all four classes of service at Huntington Beach station have been eliminated.

Because of the reduced costs of magneto repairs and elimination of the tangible but hard-to-determine expense caused by magneto failures, this preventive maintenance program has been expanded to include the six stations in the Southern divison.

Pacific has supplied its magneto shop with equipment designed for use in magneto repairs, doing away with the home-made, make-snift equipment. Magnetos for approximately 100 units are serviced at this shop. The magneto maintenance mechanic spends 50 per cent or less of his time on magneto repairs. The balance of his time is spent as a mechanic — working on engine and compressor maintenance.

Unless the magneto maintenance can be performed by a general maintenance mechanic, or the work load is approximately twice Pacific's magneto maintenance load, it would be uneconomical to set up a magneto repair shop. The magnetos from the Western division station are not sent to the shop at Huntington Beach because of the distance and time involved. A similar program of maintenance will be provided for these three stations.

A preventive maintenance program, developed by trial and error, convinces us of these things:

1. *Cost reduction can be realized by preventive maintenance.*
2. *Equipment shutdowns due to magneto failures can be almost entirely eliminated.*
3. *Magneto service, including minor inspections and setting point gaps, should be performed by a mechanic trained and skilled in magneto repairs.*
4. *It is not economically feasible to set up a preventive maintenance program for an operation the size of ours using outside labor.*
5. *To justify a full-time magneto repairman would require at least twice Pacific's magneto maintenance load.*

It is highly recommended that operations involving 100 or more magnetos be surveyed to determine the feasibility of a preventive maintenance program if only on the basis of providing dependable magneto service.

Acknowledgment

Presented at the fall meeting, California Natural Gas Association, Los Angeles, California. ★ ★ ★

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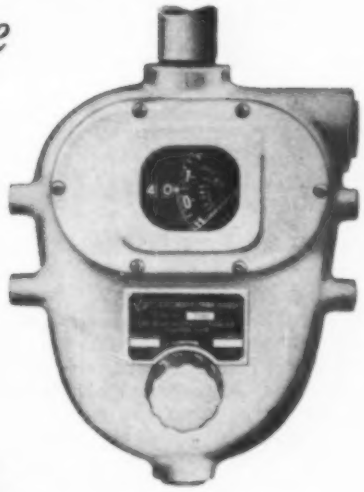

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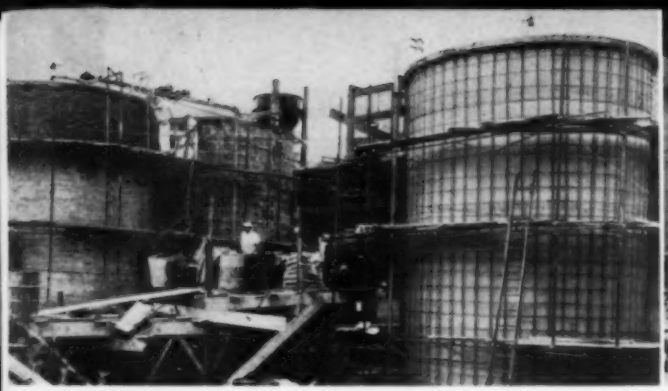
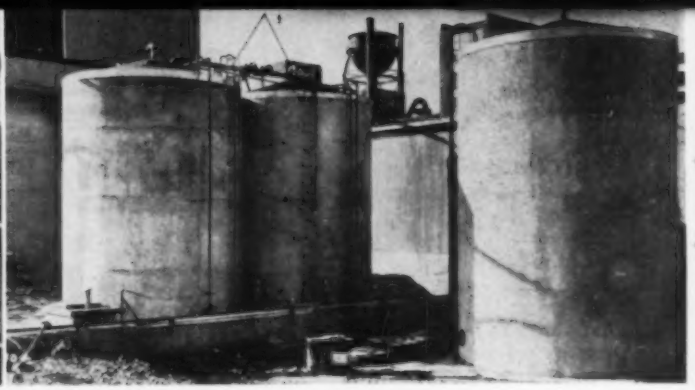




Three different construction stages in the fireproofing and insulating of tanks. In initial step, tank at right is surrounded with a paper-backed wire lath attached to a steel stud framework. Next step (center tank) is the spray-gun application of the first coats of perlite concrete. Reinforcing mesh is still visible. Final coats of perlite concrete are being applied to the tank at left. When completed, the concrete barrier measured six inches deep. **Completely fireproofed** (photo at right) tanks meet fire regulations.

Ideas at Work

Are storage tanks at your gas plant a problem? Here's a new method for securing safe storage, eliminating losses through evaporation, and minimizing maintenance costs in one operation.

Fireproofing, Insulating Storage Tanks

STORAGE tanks of all sizes can be protected from the dangers of fire and evaporation loss with a new technique employing a perlite insulating concrete. The new technique is particularly adaptable in those gas utility plants where oil is stored for use in gas manufacture. It can also be adapted for use in protecting LPG storage tanks.

Typical application of the new methods is illustrated in its use on three tanks at a Philadelphia plant. In this case, the firm involved wanted to enlarge a building that was very close to the 50,000-gal tanks, but was unable to do so because of local fire regulations. Approval was granted, however, after the tanks were fireproofed with concrete made of perlite. Perlite is an expanded volcanic mineral used in place of much heavier sand in insulating concrete.

In addition to improving fireproof qualities of a concrete, it serves as an effective insulator to minimize evaporation loss, protects metal tanks from corrosion, and helps cut tank maintenance costs. The white perlite concrete also creates a pleasing, textured, monolithic surface that is easy to keep up.

Application Is Simple

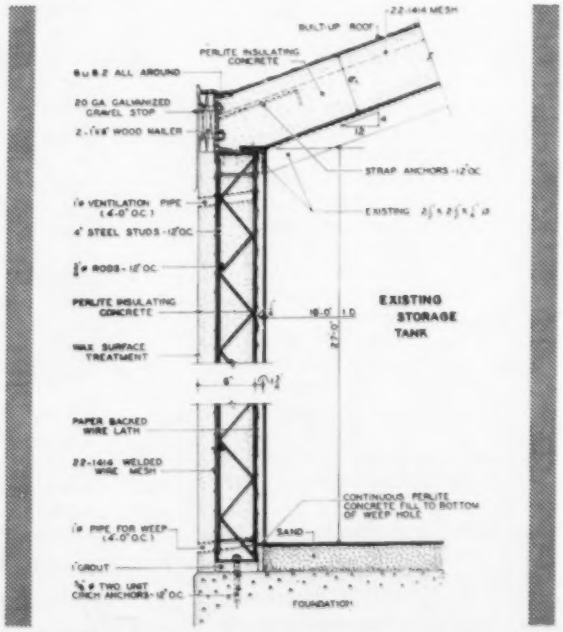
Application of a 6-in. thickness of perlite concrete around the tanks (18 ft diameter by 27-ft height) was simple, efficient, and economical. It was machine-sprayed onto a paper-backed wire lath which had been attached to a steel stud framework erected around the tanks.

This framework was connected only at the top of each tank and to runners circling the base. Thus the concrete protection was built structurally independent from the metal tank exterior so as to provide a 1¾-in. dead air space. The insulating property of the perlite concrete barrier together with the dead air space is calculated as having a U value of .16. (U equals the heat transmission in Btu per hours, per square foot, per degree F of temperature difference from air to air of a given building section.) This insulation value is equivalent to that provided by more than three feet of structural concrete.

When completed, the concrete was waterproofed. Tank tops were also protected with perlite concrete and then covered with four-ply membrane gravel roofs.

Composition of the concrete mix was as follows: 4 cu ft of perlite to 1 bag of portland cement, 5 lb Lumnite cement, 3 oz of NVX air entraining agent (vinsol resin solution) and 62 to 64 lb of water. Perlite concrete sprayed walls of this construction are approved for 4-hour retardant ratings. They may be applied with spraying equipment.

Fire-retardant quality of perlite concrete is due, in part, to the fact that perlite concrete when exposed to fire releases chemically-combined water in the form of vapor. This action limits the temperature to 212 F until all the water has been driven off. Additionally, concrete made with perlite instead of heavy aggregate has limited expansion at high temperatures. Consequently, there is a minimum of cracking upon exposure to flames preventing fire from penetrating the concrete barrier. ★ ★ ★



Cross section of fireproofed tank protected from fire hazard and evaporation loss by a 6-in. barrier of perlite insulating concrete. Concrete is sprayed onto a paper-backed wire lath attached to steel stud framework erected around the tanks. Framework was connected only at tank top and to runners circling the base. When completed, concrete surface is waterproofed with a special wax preparation.

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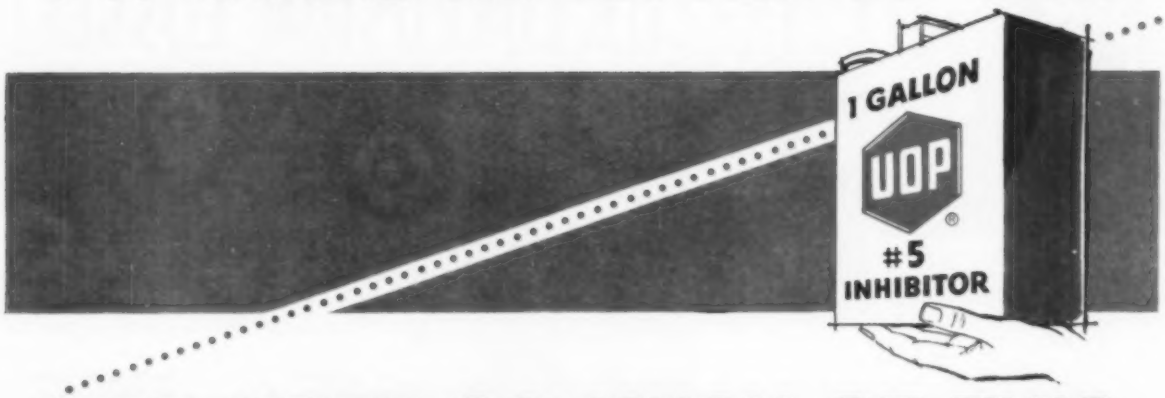

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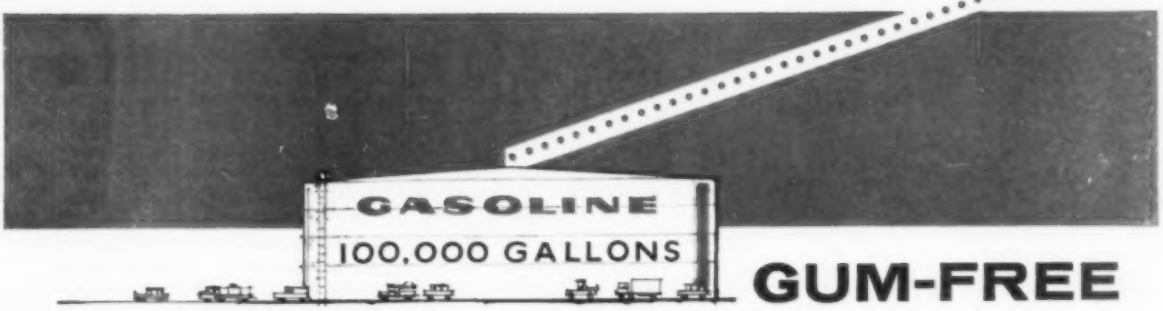

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The formation of gum in modern gasolines is the one universally recognized cause of engine manifold deposits. UOP Inhibitor #5 has been proven, by test and actual use, the best preventative for this. It's effective, too, in preventing the decomposition of TEL in stored gasolines.

UOP's technical staff has pioneered the development of techniques of finishing gasolines for maximum gum stability and engine cleanliness. Why not let us help you answer your stability problems more efficiently and at a lower cost?

UOP #5 is one of a number of UOP inhibitors and additives available to the refining industry. If you have a protection or preservation problem for product or transport facilities consult us.

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UNIVERSAL OIL PRODUCTS COMPANY

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Holiday Detection is an important step in checking a coating job before it goes below ground. But it's *after* the line is laid that the real test of how well the coating material will withstand the attack of water and soil chemicals begins. That's why coal-tar enamel is used on most important pipelines: it has proved its ability to provide long-term protection of pipeline investment.

Concrete "Corrodes," Too, under the attack of acid or alkaline solutions. Sewer pipe made of concrete is especially subject to deterioration: that's why Hoboken, N. J. is having its new sewer line protected, inside and out, with two coats of Bitumastic Super Service Black.

New Bulletin describing the important role of protective coatings in preventing corrosion is available. Request your copy by coupon below.

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CUT CORROSION LOSSES
a report by Koppers Company, Inc.

Number 10 of a series

Dr. W. F. Fair, Jr.
Corrosion Consultant

Since the security of a multi-million dollar investment is at stake, preventing corrosion in buried steel pipelines is extremely important. In this field the decisions made as to corrosion-prevention practice in the *design* phase are irrevocable—and can prove tremendously expensive if wrong.

* * *

Hot applied coal tar enamels have been traditionally the primary part of the protection system on pipelines. In recent years, cathodic protection has become widely accepted as a supplement to coatings. Enamels must now be judged as much on their value as long-term insulating materials as on their ability to prevent corrosion.

* * *

The best clue to a coating's performance is its ability to resist penetration by water. It is this inherent characteristic that determines a coating material's performance underground, with or without supplementary cathodic protection. As a coating absorbs water, it provides a decreased resistance to the flow of electric current between pipe and soil which is part of the corrosion process. Ultimately, water absorption leads to coating deterioration, which exposes bare pipe. In conjunction with cathodic protection, the coating system's most important function is that of a long-lasting electrical insulator so that impressed current requirements are kept to a minimum. Here too, a coating system's resistance to water penetration determines its performance. Actual pipeline operating experience has shown that the cost differential between maintaining cathodic protection on well and poorly insulated lines can amount to hundreds of thousands of dollars yearly.

* * *

Independent laboratories and industrial researchers have expended considerable time and effort in determining water absorption rates of protective coatings. Long-term tests have demonstrated, without exception, that coal-tar enamels have the highest resistance to water absorption among protective coating materials commercially available today.

The key to a coating's ability to resist water absorption seems to depend on the inherent molecular structure of the base material. The relative performance of a number of coatings in these various tests indicates that coating impermeability depends upon *aromatic content*. Coal tar enamel binders with an aromatic content in excess of 90%, show excellent water resistance in all tests while less aromatic materials show comparably poorer performance. Materials high in paraffinic content have been shown to leach under extended immersion.

* * *

An audio-visual meeting presentation discussing this important subject in detail is available. If you are interested in having a group-showing of this material—which includes a sound film—please address your inquiries to "How Long Should A Pipeline Last?," Koppers Bldg., Pittsburgh 19, Pa. or to Koppers District Offices: Boston, Chicago, Los Angeles, New York, Pittsburgh and Woodward, Ala. In Canada: Koppers Products, Ltd., Toronto, Ontario, and Edmonton, Alberta.

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Canadian News Notes

Trans Mountain Oil Pipe Line Company's 1957 construction program has been almost completed, with the tying in of the first 50-mile loop between Hinton and the Bickerdike pumping station, and completion of pipelaying on the second 50-mile loop coming into Kamloops station from the north. This loop has not yet been filled with oil. Dutton-Williams Brothers, Ltd., was the contractor on the first loop and Conyes Construction Company on the second.

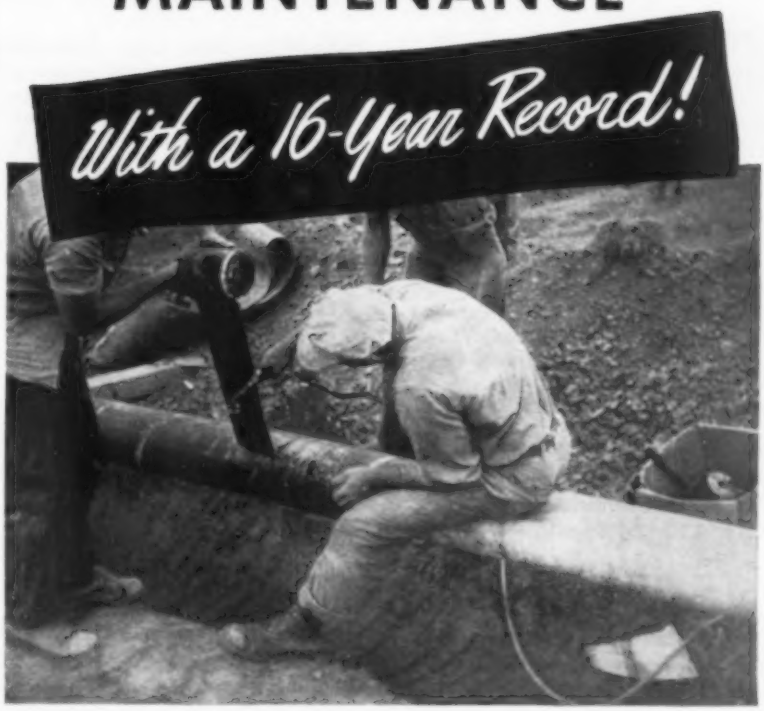
New loops will increase the rated throughput capacity of the line to 240,000 bbl per day, which will be considerably above the prospective traffic volume at least to the end of 1957. It is thought that there may be some slight seasonal bulge in 1958 that will permit volume to rise above 200,000 bbl per day, but the forecast for 1957 second half, unofficially, is around 150,000 to 160,000 bbl per day.

The second half volume for 1957 likely will average about the same as last year, reflecting the large amount of offshore business that developed out of the scarcity of transportation and the high tanker tariffs, especially after the closing of the Suez Canal. For a short period in the first half of 1957 there was available emergency business in excess of Trans Mountain's capacity. This situation is not expected to arise again, so far as it is possible to forecast. It is understood that the first of the new refineries on Puget Sound will not be ready until early in 1959 and the other probably not until 1960. These are the only visible additions to the normal demand from the domestic British Columbia refineries and those on Puget Sound.

Westcoast Main Line Finished. Westcoast Transmission Company's 30-in. 649-mile main line, which will transport natural gas from the Peace River region fields to Vancouver and across the border to the Pacific Northwest states, was completed August 9.

Section one, the most northerly part, was laid last year. Section two, under contract to Canadian Bechtel, Ltd., was tied in August 9. Section three was completed by Conyes Construction Company at the end of July, and section four tied in by Universal Pipe Lines, Ltd., the last week of July. Westcoast expected to have the line in full operation by September 1, two months ahead of schedule. Official opening is scheduled for the latter part of September.

PREVENTIVE MAINTENANCE



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Pipeline Projects

$200 Million Pipeline System for Argentina

The Argentine government has authorized the construction of a $200,000,000 pipeline system that will be built by three American contracting companies. The line will be constructed for YPF, government oil monopoly, by Fish Engineering Corporation, North American Utility and Construction Company, and Fish-Northwest Constructors, Inc.

An 815-mile gas line will be laid from the Campo Duran fields on the Bolivian border to Buenos Aires, and an oil line from Campo Duran to a YPF refinery near Rosario, 250 miles northwest of Buenos Aires.

Leonard Refineries to Lay 43-Mile Pipeline

Leonard Refineries, Inc., Alma, Michigan, has announced through its president, Reid Brazell, that a 43-mile products line will be laid from its refinery at Alma to a new terminal to be built at Lansing, Michigan.

500-Mile Gas Line Scheduled by El Paso

Western Canada's enormous natural gas reserves will be linked to gas distributing systems in Southern California through an agreement recently concluded with El Paso Natural Gas Company, it was revealed by Grove Lawrence, vice president of Southern California Gas Company, in testimony at a hearing before the California Public Utilities Commission.

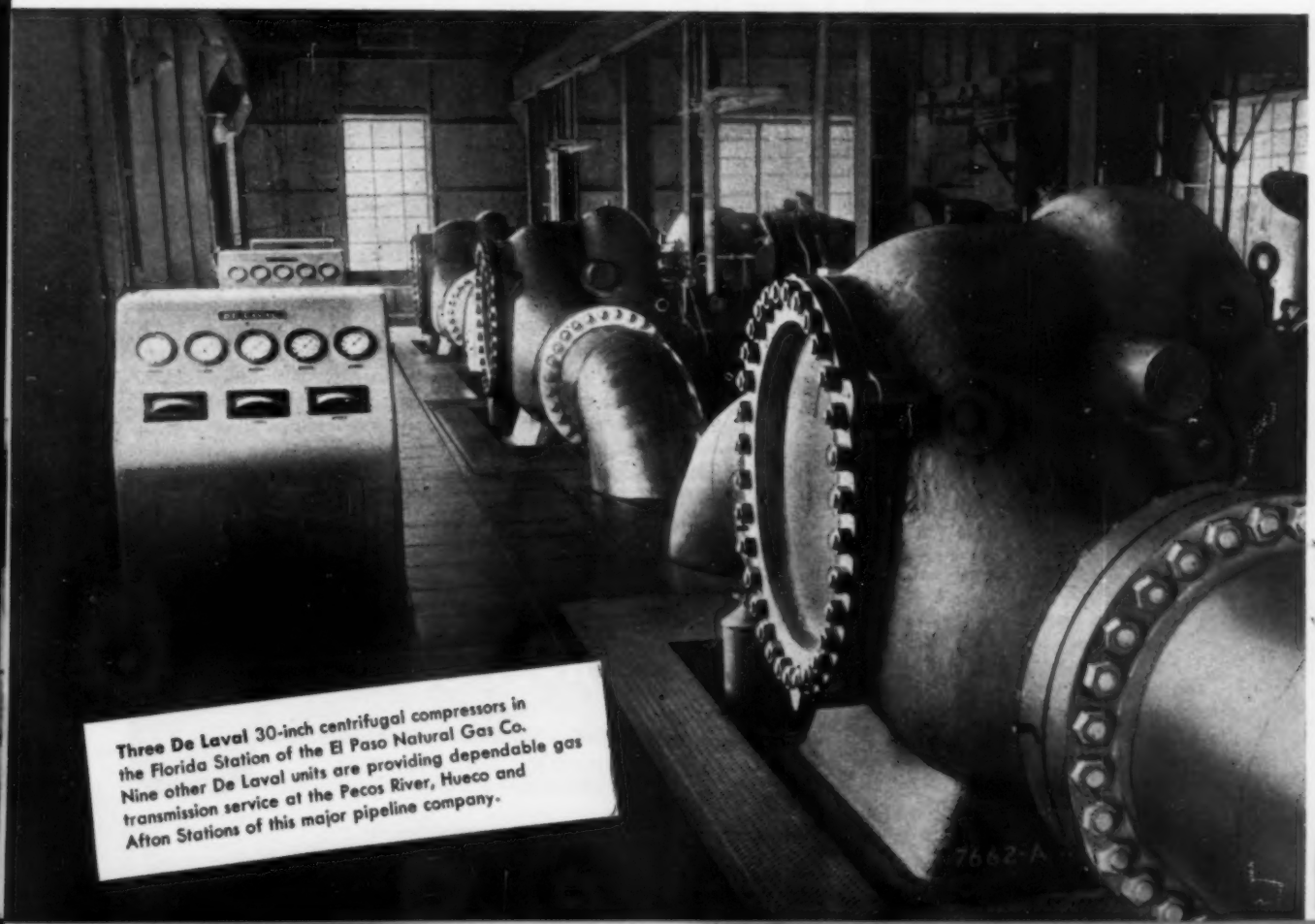
The agreement is subject to approval by the California Public Utilities Commission and the Federal Power Commission. Consent also will have to be obtained from Canadian governmental agencies.

Lawrence disclosed that Southern California and Southern Counties Gas Companies have contracted to purchase an additional 200,000,000 cu ft of gas a day from El Paso Natural, one-half to be delivered by September 1959, and the balance by September 1960. The latter company will receive the supply through an agreement with the Pacific Northwest Pipeline Company, which is contracting for Canadian gas. The El Paso company further signified its willingness to supply an additional 400,000,000 cu ft of natural gas daily in ensuing years when it is requested by the Southern California companies, Lawrence said.

The gas will travel a distance of about 2200 miles from sources in Canada to market in the Los Angeles basin. A little over 200 miles of the total distance will be from the California-Nevada border to Los Angeles.

Under terms of the agreement, El Paso will build a 500-mile long, 34-in. line to connect with the Northwest Pipeline system near Twin Falls, Idaho. Gas will be delivered to the California companies at the state line southwest of Las Vegas. Additional pipeline facilities will be required to bring it to Southern California markets.

Don't miss the 1957 Instruments and Control Equipment Directory beginning on page E-7 in this issue.



Three De Laval 30-inch centrifugal compressors in the Florida Station of the El Paso Natural Gas Co. Nine other De Laval units are providing dependable gas transmission service at the Pecos River, Hueco and Afton Stations of this major pipeline company.

Natural Gas Pipeline Files $62 Million Petition

An application by Natural Gas Pipeline Company of America for authorization for the construction and operation of natural gas facilities at an estimated cost of $62,668,000, has been accepted for filing, by the Federal Power Commission.

Natural wants to construct approximately 59 miles of loop line between compressor station No. 106, in southeastern Nebraska, and Joliet, Illinois; approximately 336.6 miles of 30-in. loop line between station No. 106 and station No. 111, in the Texas Panhandle; the addition of 29,750 hp in stations in Texas and Iowa, and additional metering facilities at the Joliet regulating station.

Natural Gas Pipeline proposes to transport an additional 185,000,000 cu ft of gas per day for resale to municipalities and local utility companies at any point on its existing system extending from Fritch, Texas, to Joliet. No additional direct sales or increase in volumes to such existing customers are proposed.

The application was filed to comply with the requirements set forth in the FPC's Opinion No. 299 and order issued December 4, 1956, in Docket No. G-4280, et al. The commission at that time authorized Natural to construct facilities to enable it to tap natural gas reserves in northern Texas and southwestern Oklahoma and authorized Lone Star Gas Company, Dallas, Texas, to sell a maximum of 100,000,000 cu ft of gas per day to Natural at a point in Stephens County, Oklahoma.

The FPC's order provided that if Lone Star accepted the certificate authorizing the gas sale, Natural must file a certificate application requesting commission authorization to build the necessary facilities to increase its present system sales capacity to transport the gas to be recieved from Lone Star. Lone Star accepted its certificate on February 12, 1957.

Michigan Wisconsin to Construct Loop Lines

Michigan Wisconsin Pipe Line Company has been authorized to construct and operate 22 miles of 24 in. loop line in Illinois and Wisconsin at an estimated cost of $1,823,000.

The company's applications to FPC stated that the construction of the two 11-mile segments will result in the complete looping of its main line serving Wisconsin and provide a safety factor in the event of a line break. No additional service is contemplated by means of the additional facilities.

Contract Awarded for Muskegon Pipe Line

Midwestern Constructors, Inc., of Tulsa, Oklahoma, has been awarded a contract to construct a 165-mile crude oil pipeline for the Muskegon Pipe Line Corporation.

The new 10-in. line will be built from Griffith, Indiana, to Muskegon, Michigan. To connect with the Service Pipe Line Company system at Griffith, starting point of the new line, Muskegon Pipe Line system will serve refineries in western Michigan. It will be connected to the Aurora Gasoline Company and the Naph-Sol Refining Company refineries in Muskegon.

Muskegon Pipe Line Corporation was organized by Aurora Gasoline Company of Detroit and the Service Pipe Line Company of Tulsa. Service, as construction and operating agent for Muskegon, will supervise construction and on completion of the system late in 1957, will supervise operation.

The new system will have an initial capacity of about 26,000 bbl per day. It will be able to deliver three different types of crude oil to the refineries without intermingling. A pump station will be erected at Griffith, and the system is designed for construction of another station on the route of the line to Muskegon at a later date.

DE LAVAL

CENTRIFUGAL COMPRESSORS

on the job at El Paso Natural Gas

De Laval centrifugal compressors offer many important engineering features. (1) They are designed to handle an increased ultimate flow, can be quickly converted to larger capacities by replacing the impeller, diaphragm and a few minor parts. (2) The high pressure shaft seal eliminates leakage, consumption of sealing oil is negligible. (3) There is only one moving part—the rotor—which has ample clearance. (4) Units are compact, require smaller foundations and smaller stations. (5) First costs and installation costs are low.

Bulletin 503 gives data on De Laval Centrifugal Compressors. Write for your copy.

DE LAVAL *Centrifugal Compressors*

DE LAVAL STEAM TURBINE COMPANY

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DL378

Ohio Fuel to Lay Additional Gas Lines

Ohio Fuel Gas Company has been authorized by the Federal Power Commission to construct about 29.8 miles of 24-in. loop line from its Pavonia compressor station in Richland County to Attica in Seneca County, Ohio; approximately 11.2 miles of 20-in. and 11.3 miles of 18-in. line extending from Gibsonburg, Sandusky County, to Toledo, and approximately 0.8 miles of 4½-in. service line to provide a direct, interruptible, industrial service to Basic, Inc., in Ottawa County.

Mississippi River to Add Facilities

The Federal Power Commission has authorized Mississippi River Fuel Corporation to build 6400 additional hp in existing compressor stations and 54 miles of 26-in. pipeline paralleling sections of its existing system in Louisiana, Missouri, and Arkansas. The company was also authorized to construct additional field facilities in Louisiana to deliver natural gas to Texas Gas Transmission Corporation, for redelivery to Mississippi near Perryville, Louisiana. Cost of the facilities is estimated at $6,936,600.

Throughout the oil world there are thousands of Roper Series F Pumps on the job. Big reason is *dependability*. Other reasons include: smooth, non-pulsating flow . . . equal size gears running in axial hydraulic balance . . . positive displacement requiring no priming . . . and importantly, four-port design. This latter feature of the Roper Series F Pump allows greater flexibility of installation . . . cuts installation time and costs. Four-port design, you see, permits 8 optional piping arrangements — 4 for CW and 4 for CCW operation. There are other Ropers in the line . . . in the pumping range and pressure range you require. Ask your distributor for all the facts . . . he'll show you how Roper can give you better service and higher efficiency in field storage, gathering line, and tank truck installations.

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Gas Gathering System For Bee County, Texas

Construction of a new million dollar 45-mile Bee County Gas Gathering System and the purchase of a one-half interest in the 20-mile Duval Gas Gathering System has been announced by Oscar S. Wyatt, Jr., president of Coastal States Producing Company.

The Bee County, Texas, system will be 50 percent owned by Coastal States and will serve two proved gas fields with multi-producing zones. Initially, the system will have in excess of 70 billion cu ft of gas reserves dedicated under long-term contract for delivery to the system. The new pipeline, which will connect with the main pipeline of Texas Eastern Transmission Company.

The acquisition of a half interest in the Duval system included a 50 percent ownership of a well with an estimated reserve of approximately 8 billion cu ft of gas.

Gas reserves dedicated to this system under long-term contract, without taking into account plans to revise and extend the pipeline, are presently estimated to be in excess of 100 billion cu ft.

United Proposes Line For Direct Service

An application by United Gas Pipe Line Company seeking authority for the construction and operation of natural gas facilities to provide direct interruptible industrial service in Mississippi has been accepted for filing, the Federal Power Commission announces.

United proposes to construct approximately 17.7 miles of 12-in. pipeline and appurtenant facilities from a point of connection with its main Lirette-Mobile 12-in. transmission line in Jackson County, south to the Bayou Casotte industrial area about two miles east of Pascagoula, Mississippi.

Northern Natural to Build in Hansford County

Northern Natural Gas Company will construct natural gas facilities in Hansford County, Texas, having a net cost of about $1,651,332, by recent authorization of the Federal Power Commission. The project will consist of 12.7 miles of 16-in. to replace an existing 10-in. line; added capacity to the Spearman dehydration facilities by 50,000,000 cu ft per day, and construction of certain additional field line and measuring facilities. The cost of the proposed construction is approximately $1,923,100. Northern also proposes to remove the 10-in. line and about 14 miles of gathering lines at an estimated cost of about $58,532. The company expects to obtain about $330,300 from the salvage.

Pacific Northwest Gets OK on Three Projects

The Federal Power Commission has authorized Pacific Northwest Pipeline Corporation to construct and operate natural gas facilities in Washington, Colorado, and Idaho at an estimated cost of $2,375,692.

The FPC, in Docket No. G-12, 221, authorized Pacific Northwest to construct 34.5 miles of 4 and 6-in. lateral pipeline from its 26-in. line Sonohomish County, Washington, to a measuring and regulating station at the Northwestern Portland Cement Company plant at Grotto, Washington.

In Docket No. G-12, 269, Pacific Northwest was authorized to construct 4.5 miles of 3½-in. lateral line to extend from its existing 6⅝-in. Uravan lateral line to Union Carbide Nuclear Company's plant at Slick Rock, San Miguel County, Colorado.

In Docket No. G-12, 327, Pacific Northwest was authorized to construct 41 miles of 6⅝-in. line from its 6⅝-in. Coeur d'Alene lateral to a metering station at the Bunker Hill Company plant near Kellogg, Shoshone County, Idaho.

Last month the Commission granted Pacific Northwest temporary authorization to construct and operate the Northwestern and Bunker Hill connections.

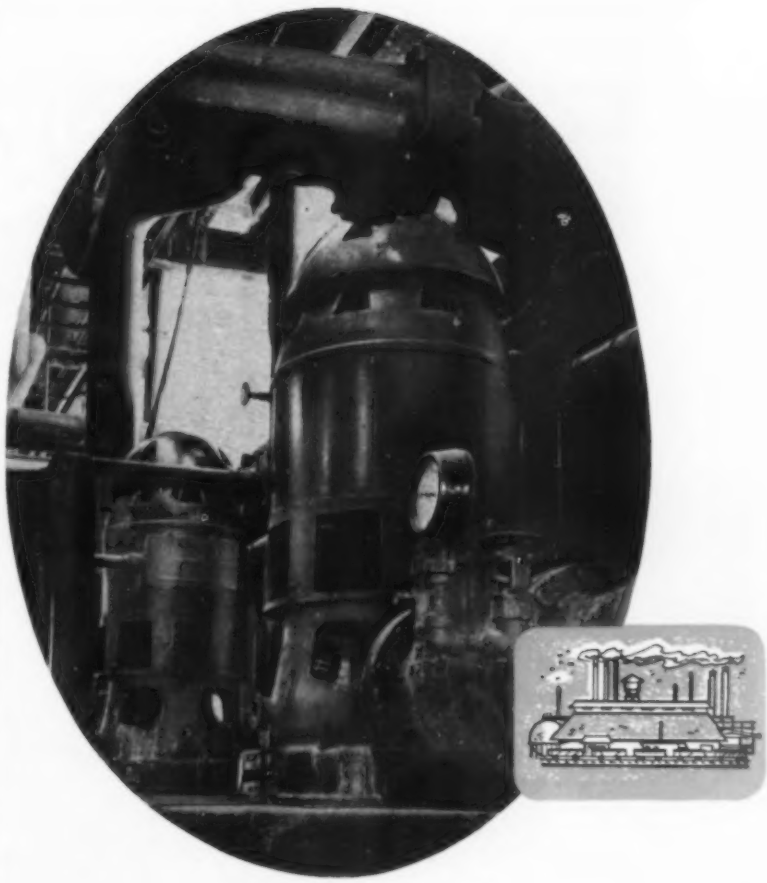
In addition, Pacific Northwest has stated that it expects to seek authority in the fall of 1957 to supply the natural gas requirements for Cataldo, Wardner, Kellogg, Osburn, and Wallace, Idaho, which are adjacent to the proposed Bunker Hill line.

Plan Facilities for More Gas Purchases

Texas Eastern Transmission Corporation and Wilcox Trend Gathering System, Inc., have been authorized to construct natural gas facilities during the year 1957 costing approximately $4,000,000.

Both companies in their applications stated that the exact description of the facilities to be constructed is unknown. Texas Eastern estimates the overall cost of its proposed facilities at not over $3,000,000, with no single project to exceed $500,000. Wilcox estimates the cost of its proposed facilities at not more than $1,000,000, with no single project over $150,000.

The stated purpose of the proposed facilities is to enable the applicants to purchase natural gas from independent producers along the present and established transmission pipelines. The applicants' systems are integrated and coordinated so as to supply the same customers in the same market areas.



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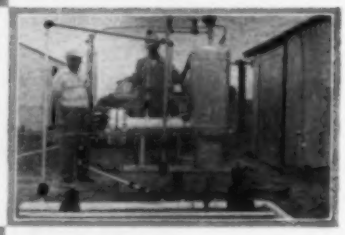

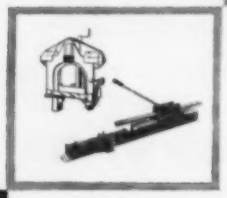

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Projects

Southern Natural to Take More Offshore Gas

The Federal Power Commission has authorized Southern Natural Gas Company to construct pipeline facilities, estimated to cost about $7,595,000, to connect its transmission system to additional natural gas reserves in 10 fields located in, and the offshore areas adjoining, Plaquemines, St. Bernard, and Jefferson parishes, Louisiana.

Southern will build a total of about 60 miles of pipeline, 7260 hp in compressor capacity, and meter and regulating stations in southern Louisiana to connect its system with the additional gas reserves. The FPC also authorized Southern to make changes in a pipeline construction project authorized last March, to provide the necessary capacity to handle the increased volumes of gas produced in the southern Louisiana area as they become available from the 10 fields. Southern plans changes in the sizes and mileage of the previously authorized pipeline and the elimination of a 1350-hp compressor unit. The changes will increase the capacity of the facilities from 24,400,000 cu ft per day to 80,000,000 cu ft, while the cost will be decreased from $1,538,000 to $1,415,780.

Natural Gas Storage Facilities Authorized

The Federal Power Commission has authorized Natural Gas Storage Company of Illinois, of Chicago, Illinois, to construct and operate natural gas storage facilities in the Cooks Mills area of Coles and Douglas counties, Illinois.

The facilities required for the development and operation of the new storage field consist of wellhead installations; 3.59 miles of field lines; a 1650-hp compressor plant for injection and withdrawal; dehydration facilities; approximately 14.75 miles of 20-in. line to connect the storage field to the 30-in. main transmission line of Texas Illinois Natural Gas Pipeline Company; a meter station at the interconnection, and wells drilled into the storage formation.

The estimated cost of the facilities is approximately $3,729,000. The FPC granted temporary authority for the facilities in May 1957. The Cooks Mills area includes two non-associated gas reservoirs known as the Cypress and Rosiclare formations. These formations will be utilized for the underground storage of gas in conjunction with the operation of Natural Gas Storage's present underground reservoir near Herscher, Kankakee County, Illinois.

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD

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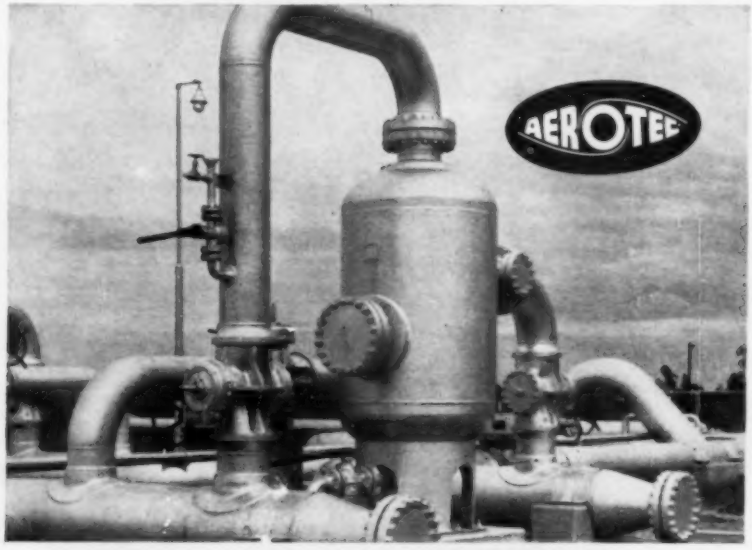
WITH THE PIPELINE CONTRACTORS

● **Fulton Banister, Ltd., 625 Northern Hardware Building, Edmonton, Alberta.** Has 100 miles of 18-in. for *Alberta Gas Trunk Line Company, Ltd.*, from Burstall at the Alberta border to Provost, Alberta. Also has 22 miles of gas gathering line in the Provost field for *Provo Gas Producers, Ltd.*, consisting of constructing gathering system and wellhead tie-ins—3 to 12-in. pipe; this gas to be fed to Alberta Gas Trunk Lines.

● **Banister Construction, Ltd., 625 Northern Hardware Bldg., Edmonton, Alberta.** Has undetermined amount of 2 to 6-in. extensions to existing systems in cities and towns in Saskatchewan, plus approximately 5000 consumer service connections, for *Saskatchewan Power Corporation*. Has contract for construction of transmission and distribution system in the town of Wilkie, Saskatchewan, for the *Saskatchewan Power Corporation*.



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● **Williams Brothers Company, National Bank of Tulsa Bldg., Tulsa, Oklahoma.** Has 212.5 miles 20-in. crude line for *Socony Mobil Oil Company de Venezuela*. Line will extend from San Silvestre field to Puerto Cabello on the Caribbean Coast. Also has 127 miles of 30-in. loops for *Texas Eastern Transmission Corporation;* work is divided into three jobs from Egypt, Mississippi to Barton, Alabama; Berne, Ohio to Holbrook, Pennsylvania; and Holbrook to Uniontown, Pennsylvania.

● **H. C. Price Company, Box 1111, Bartlesville, Oklahoma.** Has 71 miles of 30-in. line for *Texas Eastern Transmission Corporation* in the Port Lavaca, Texas, area. Has contract for construction of 343 miles of 30-in. pipeline loops for same company, consisting of six jobs in Tennessee, Kentucky and Ohio.

● **Sheehan Pipe Line Construction Company, National Bank of Tulsa Bldg., Tulsa, Oklahoma.** Has 116 miles of 8-in. line for *Buckeye Pipe Line Company* between Huntington and Griffith, Indiana; project includes take-up, reconditioning and relay. Also has 70 miles of 8-in. line to recondition for *Buckeye Pipeline Company* near Cooks Ferry, Ohio.

● **Canadian River Construction, 580 Hornby Street, Vancouver, British Columbia.** Has 150 miles of gathering lines in northern Alberta and British Columbia for *Westcoast Transmission Company, Ltd.*

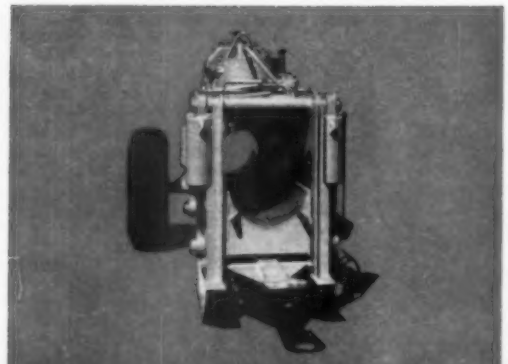
● **Troth Construction Company, Box 592, Britton, Oklahoma.** Has contract for 160 miles of 2 and 8-in. lines for gas distribution to communities in the Aberdeen, South Dakota, area, for *Northern Natural Gas Company*.

● **Engineers Limited Pipeline Company, 200 Bush Street, San Francisco, California.** Has line for *Pacific Gas & Electric Company* consisting of 37 miles of 20-in., 37 miles of 18-in., and 19 miles of 12-in. to lay from Beehive Bend field to Sacramento, California. Has joint venture with J. E. Young, Pipe Line Contractor, Inc., on two sections of *Southern Pacific Pipe Lines, Inc.*, new products line. Contract involves 184 miles of 6 and 8-in. line between Roseville, California, and Fallon, Nevada. Also has joint venture with Alex Robertson Company to construct 165-mile, 12-in. gas line for *Pacific Gas and Electric Company* from Tehama Count to Humboldt Bay area.

● **Mannix, Ltd., 322 Seventh Avenue W., Calgary, Alberta.** Has 100 miles of 3 to 12-in. gathering line in the Pembina field to lay for *Pembina Pipeline Company, Ltd.* Has 110 miles of 30-in. for *Westcoast Transmission Company, Ltd.*, between Huntingdon and Kingsvalle, British Columbia. Has 90 miles of 34-in. to lay for *Trans-Canada Pipe Line Company* between Moose Jaw and Candiac, Saskatchewan. Has contract to lay 32 miles of 16-in. loop for *Pembina Pipe Line Company, Ltd.*, between Edmonton and Calmar, Alberta.

● **Mid-States Construction Company, P. O. Box 417, Mt. Vernon, Illinois.** Has 24 miles of ¾ to 6-in. distribution line for *Illinois Power Company* for systems in Carlyle and Hoffman, Illinois. Also has 8½ miles of 6 and 4-in. line for the same company between Hoffman and Carlyle.

FOR FURTHER INFORMATION ON ADVERTISED PRODUCTS, SEE READER SERVICE CARD



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Contractors

● **C. P. Bartley & Son Pipe Line Construction, P. O. Box 616, Tioga, North Dakota.** Has 121 miles of 2 through 12-in. gas gathering extensions for *Signal Oil & Gas Company* in the Newton, North Dakota, area.

● **Houston Contracting Company, 2707 Ferndale Place, Houston 6, Texas.** Has 43 miles of 30-in. natural gas line for *Texas Eastern Transmission Corporation* between Berne and Athens, Ohio. Also has 39 miles of 30-in. gas line for *Texas Eastern* between Wheelersburg and Athens, Ohio. Has 80 miles of 30-in. gas line for *Texas Eastern* from Kosciusko to Egypt, Mississippi. Has 80 miles of 30-in. natural gas line for *Northern Ontario Pipe Line Crown Corporation* between Uspala and Port Arthur, Ontario. Also has 33 miles of 6, 8, and 10-in. lateral gas lines for *Tennessee Gas Transmission Company* in the vicinity of Southwest Pass below New Orleans, Louisiana. Has 20 miles of 18-in. natural gas line reconditioning for *Texas Gas Transmission Corporation* near Bastrop, Louisiana.

● **Hood Construction Company, 3002 E. Century Blvd., Lynwood, California.** Has 81 miles of 10-in. line for *Southern Pacific Pipe Lines, Inc.*, beginning west of Lodi and running to a point near Roseville, California; this is second section of firm's 323 mile products line.

● **J. E. Young, Pipe Line Contractor, Inc., 931 E. Rosecrans Avenue, Los Angeles, California.** Has joint venture with Engineers Limited on two sections of the 323 mile *Southern Pacific Pipe Lines, Inc.*, new products line. Contract includes 184 miles of 6 and 8-in. line extending from Roseville, California, to Fallon, Nevada.

● **Dutton-Williams Bros., Ltd., North Canadian Oils Building, Calgary, Alberta.** Has approximately 320 miles of distribution and transmission systems for *Inland Natural Gas Company* in and connecting several British Columbia towns. Project includes 154.5 miles of 12 in. line, 110 miles of 10 in., and remainder from 8 to ¾-in. in Nelson, Savona, Penticton, Castlegar, Kelowna, Kamloops, and Grand Forks. Also has contract for 47.5 miles of 12-in. oil line from Gilbey to Sundre for *Rangeland Pipe Line Company*. Has contract for testing 310 miles of *Westcoast Transmission, Ltd.*, 30-in. line from Taylor, B. C., to M. P. 310; completion is expected in September. Has contract for 50.8 miles of 30-in. oil line for *Trans Mountain Oil Pipe Line Company* between Edson and Minton, Alberta.

● **Fish Service Corporation, M & M Building, Houston, Texas.** Has 67 miles of line for *Florida Pipeline and Storage Company* from Port Everglades to Homestead Air Force Base, Florida.

● **Midwestern Constructors, Inc., 105 North Boulder, Tulsa 3, Oklahoma.** Has 34 miles of 12-in. paralleled line for *Great Lakes Pipe Line Company* between Tulsa and Barnsdall, Oklahoma.

● **Somerville Construction Company, Ada, Michigan.** Has 98 miles of 6-in. line to lay for *Texaco-Cities Service Pipe Line Company* between Lowell, Michigan, and South Bend, Indiana.

● **Eastern Pipeline Contractors, Mercantile Bank Bldg., Dallas, Texas.** Has contract for 89 miles of 6 and 8-in. line for *Gulf Refining Company*, from a point westward from Midland into New Mexico, near Hobbs.

● **Dunn Bros., Inc., 801 Mercantile Securities Bldg., Dallas, Texas.** Has stringing contract with H. C. Price Company on 69 miles of 12-in. line for *Texas Eastern Transmission Company* between Chicago and Ashton, Illinois. Also has similar contract with same companies for stringing approximately 230 miles of 30-in. in Alabama, Tennessee, and Kentucky. Is stringing 32.5 miles of 30-in. for *Tennessee Gas Transmission Corporation* between Winchester and Richmond, Kentucky. Is stringing 76.5 miles of 16-in. between Aneth, Utah, and Kayenta, Arizona, and 86 miles of 12-in. between the Mesa station in Utah and the Bisti oil field in New Mexico for the *Four Corners Pipeline Company* (the A. P. V. Company is prime contractor). Will string 27.5 miles of 34-in. near Leupp, Arizona, for *El Paso Natural Gas Company*. Will string 85 miles of 14-in. between Columbus and Lebanon, Indiana, for *Texas Eastern Transmission Corporation* (H. L. Gentry is prime contractor). Also has 93 miles of 14-in. between Lebanon and Schnieder, Indiana, for the same company with Latex Construction Company acting as prime contractor.

● **R. H. Fulton & Company, Inc., P. O. Box 1526, Lubbock, Texas.** Has 252 miles of 22-in. line for *Colorado Interstate Gas Company* between Rock Springs and Laramie, Wyoming. Has 78.4 miles of 26-in. line in the Minnesota section of *Interprovincial Pipe Line Company's* main line loop. Has contract for sections 3, 5 and 6 of the new *Four Corners Pipe Line Company* line. Section 3 is a 16-in. line 98 miles long from Cameron to Seligman, Arizona; this work began July 1. Sections 5 and 6 are to begin October 15 to avoid crossing desert during hot summer. Section 5 is 105 miles of 16-in. line from the Colorado River to Twentynine Palms, California and Section 6 is a 46-mile 16-in. section from Twentynine Palms to Olive, California. Also has 93 miles of 8-in. for *Great Lakes Pipe Line Company* from Newport, Minnesota to Chippewa Falls-EauClaire, Wisconsin area.

● **F. E. Shaw, Ltd., 530 S. Vidal Street, Sarnia, Ontario.** Has 40 miles of 6 to 10-in. line for *Dominion Natural Gas Company, Ltd.*, in the Brantford, St. Catharines, and St. Thomas districts. Has 8 miles of 16-in. line for *Dow Chemical of Canada, Ltd.*, from new salt bed location to the Sarnia district. Has 14 miles of 16-in. loop line around the city of Hamilton, Ontario, for *United Gas and Fuel Company*. Has 67 miles of 6 to 20-in. transmission lines for *Union Gas Company*, Chatam, Ontario, to Dawn, London, St. Marys, Stratford, Kitchener and Guelph. Has 12 miles of 2, 4, 6, and 8-in. distribution line for the *Consumers Gas Company* of Toronto in the town of Newmarket, Ontario.

● **Robert B. Somerville Company, Ltd., 4891 Yonge Street, Toronto, Ontario.** Has joint venture with Sheehan Constructors for 91 miles of 20-in. line between Sarnia and Bright, Ontario, for *Interprovincial Pipe Line Company*. Job started May 13.

● **Vaughn & Taylor Construction Company, Inc., Box 3266, Odessa, Texas.** Has approximately 30 miles of 4 to 24-in. gathering lines for *Phillips Petroleum Company* in the Pembrook area of West Texas.

● **Engineering-Construction Company, First National Bank Building, Tulsa, Oklahoma.** Has contract with *City of Macon, Missouri*, to lay 25 miles of 4 and 6-in. between Moberly and Macon, Missouri, and 12 miles of various size distribution lines in Macon.

● **Sheehan Constructors of Canada, Ltd., Toronto, Ontario.** Has joint venture with Robert B. Somerville Company, Ltd. for 91 miles of 20-in. line between Bright and Sarnia, Ontario, for *Interprovincial Pipe Line Company*.

● **Potashnick Construction Company, Box 423, Cape Girardeau, Missouri.** Has joint venture with A. P. Vaughn Construction Company to lay sections 1 and 2 of *Four Corners Pipe Line Company* crude line between Utah and California. Both sections are 16-in. pipe; Section 1 is 76 miles from the Aneth field in Utah to Kayenta, Arizona; Section 2 runs 98 miles from Kayenta to Cameron, Arizona. Work on both sections began June 15.

● **Oklahoma Pipe Line Constructors, P. O. Box 13227, Dallas 20, Texas.** Has 35 miles of 30-in. for *Tennessee Gas Transmission Company* between a point in Garrard County, Kentucky, to a point of TGT's compressor site in Powell, Kentucky. Also has 85 miles of 20 and 24-in. (spread 101) of Trans-Canada Pipe Lines, Ltd., on the eastern section, in proximity of Toronto, Ontario, beginning from a point southwest of Toronto circling the city, and also a section beginning at a point east or northeast of Toronto.

● **Brown & Root, Inc., 4100 Clinton Drive, Houston, Texas.** Has contract with *Texas Eastern Transmission Corporation* to furnish field supervision for construction of 626 miles of 30-in. loops along the company's line between Beaumont, Texas, and Uniontown, Pennsylvania.

● **Midwestern Contractors, Inc., 130 West Liberty Drive, Wheaton, Illinois.** Has contract for 69-mile, 12-in. extension of *Great Lakes Pipe Line Company* line from Middlebury Junction into Chicago, Illinois.

● **Majestic Contractors Limited, 408 Royal Trust Building, Edmonton, Alberta.** Has an 82-mile 30-in. spread for *Trans-Canada Pipe Lines, Ltd.*, from St. Anne, Manitoba, to the Ontario border. Also has contract for testing a 34-in. spread of the Trans-Canada line between Burnstall, Saskatchewan and Winnepeg, Manitoba. Has 65 miles of 20-in. line for *Interprovincial Pipeline, Ltd.*, between Sarnia and Port Credit, Ontario. Has contract for 4 to 12-in. gathering system for *Producers Pipeline, Ltd.*, in the Estavan, Saskatchewan area. Has city distribution system in Cooksville, Ontario, for *Consumers Gas Company* of Toronto. Also has city distribution system for Guelph, Ontario, for *Union Gas Company of Canada, Ltd.*

● **A. P. Vaughn Construction Company, Box 1144, Fort Worth, Texas.** Has joint venture with Potashnick Construction Company to lay sections 1 and 2 of the Utah to California crude line for *Four Corners Pipe Line Company*. Both sections are 16-in. pipe. Section 1 is 76 miles from the Aneth field in Utah to Kayenta, Arizona; Section 2 runs 98 miles from Kayenta to Cameron, Arizona. Work began June 15.

● **O. R. Burden Construction Corporation, P. O. Box 5216, Tulsa, Oklahoma.** Has contract for 185 miles of 20-in. crude line for the *Tecumseh Pipe Line Company* to extend from Scherville, Indiana, to Cygnet, Ohio. Has contract for 25 miles of 20-in. in the Bloomfield and Madison townships, Ohio, for the *Ohio Fuel Gas Company-Columbia Gas System*. Has been awarded contract to lay 120 miles of 16-in. and 4 miles of 12-in. crude line for *Magnolia Pipe Line Company* between Abilene and Midland, Texas.

● **Collins Construction Company, P. O. Box 86, Port Lavaca, Texas.** Has 26 miles of 6 to 12-in. to lay offshore for the *CATC Group* from Grand Isle, Louisiana, to a point 26 miles out into the Gulf of Mexico. Marine Gathering Corporation is the prime contractor, and Collins is burying the line being laid by Marine Gathering's pipeline laying barge. Also has 12,000 ft of 24-in. for *Tennessee Gas Transmission Company*, with Pentzien, Inc., the prime contractor; job is three river crossings installed in a downstream catenary across the Mississippi River at Greenville, Mississippi.

● **Latex Construction Company of Georgia, Box 56, Northside Station, Atlanta, Georgia.** Has contract for 93 miles of 14-in. between Lebanon, Indiana, and the south bank of the Kankakee River for *Texas Eastern Transmission Corporation*.

● **Price-Poole Pipeline Constructors of Canada (joint venture of H. C. Price of Canada Limited and Poole Construction Company, Ltd.), Rivers, Manitoba.** Has 99-mile section of 34-in. pipe to lay for *Trans-Canada Pipe Line Company* on a section of line in Manitoba Province extending eastward from the Assiniboine River near Miniota. Right of way has been cleared and limited activity is underway prior to actual construction beginning this spring as weather permits.

● **Williams-Austin Construction Corporation, 3322 Grant Building, Pittsburgh 19, Pennsylvania.** Has 50 miles of 10-in. for *Central Hudson Gas & Electric Company* between Kingston and Albany, New York. Also has 5.7 miles of 26-in. line for Atlantic Seaboard Corporation in Hardy and Grant counties, West Virginia.

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For additional information see page 107, Pipe Line Composite Catalog

NEW Pipeline Equipment

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For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

New Portable Microwave System is Rugged and Light. Microwave system was designed and manufactured in France and is being distributed by the Intercontinental Electronics Corp. Although it weighs less than 46 lb per unit, this system can be set up in a matter of minutes. It has found high favor with the military. Comunications engineers in the oil industry have exhibited considerable enthusiasm for its many uses for communication during pipeline construction.

It is called the MX-641 microwave system and at a demonstration held in Houston, Texas, one of the links was set up

and oriented in less than 5 min. One of the components which gives this system a somewhat distinct appearance is the cigar-shaped antenna. Consisting of a disc-loaded aluminum rod with the disc varying slightly is diameter spaced according to frequency demands, the antenna has several advantages — primarily lightness and low wind resistance. This antenna is capable of producing a gain of 18 decibel and it can be clamped on to trees, telephone poles, derricks and the like. The length of the antenna is not critical; however the longer it is, the more directional it becomes.

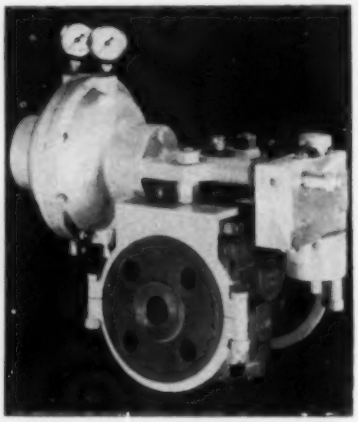
The equipment operates in the 2000 mc band. The equipment requires voltage from 105 to 240 and has 12 channels and it can be set for 13 channel operation. *Intercontinental Electronics Corp.*

Circle number (81) on reply card.

Gas Analyzer. The Ranarex Gas Analyzer measures specific gravity of a gas or gas mixtures, compared to air or other reference standards. The simple, rugged instrument provides a constant, reliable analysis comparable to that obtained with complex and costly chemical, electrical or optical methods. Ranarex Gas Analyzers are used for combustion analysis in power plants, in gas utilities and pipelines, in oil refineries, in chemical process and metal treating industries. *Permutit Company.*

Circle number (82) on reply card.

Positioner-Actuator. Bettis positioner-actuator allows modulating control of plug valves. The positioner is designed for attachment to standard Robotarm diaphragm actuators. Modulating operation can be obtained from instrument signals of 3 to 15 psi, 3 to 15 oz, or high-pressure air or hydraulic ranges, as required. Use of the positioner also makes possible conversion of plug valves into regulators or relief valves. *Bettis Corporation.*



Circle number (83) on reply card.

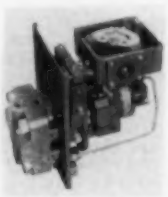
Electronic Meter. The Burgess-Manning electronic meter is a high fidelity unit operating on the null balance inductance bridge principle. Servo power at the receiver provides high power at both maximum and minimum flow rates. Refinement of a calibrated cam permits hair line accuracy at high and low flow rates. Transmission up to 5000 ft is possible. A wide selection of range tubes are available from 18.84 to 678.20 in. of water thereby providing a versatile unit suitable for all conditions of flow of liquids and gases. *Burgess-Manning Company.*

Circle number (84) on reply card.

General Petroleum Company has installed a "VAREC" pulse code telemetering system at their Wilmington, California, tank farm. At their central control office the operator can quickly obtain the liquid level of any tank or reservoir by simply dialing the tank number on a "Varec" Pulse Code Receiver. The reading flashes on the receiver and reading is charted in 5 seconds on a control panel which graphically diagrams the entire tank-farm layout. The system was manufactured by The Vapor Recovery Systems Company.

Circle number (85) on reply card.

Pneumatic Telemetering. Republic Type VP pneumatic pressure transmitters are available with diaphragm, bellows, or bourdon spring elements to fit specific job needs. Range adjustment is easy to make and is unusually broad. The Republic null-balance-vector principle of range adjustment permits this flexibility while saving space and weight and keeping ± ½ percent accuracy of scale range. *Republic Flow Meters Co.*



Circle number (86) on reply card.

Supervision and control of this petroleum pumping station from a remote point is provided by the Bendix-Pacific Electro-Span equipment. Characterized by flexibility through unitized construction, Electro-Span digital systems offer reliable and

long term unattended life. Digital transmission maintains accuracy without the need of precise measurement of pulse height, pulse width, voltage, or frequency. Virtually any number of telemeter and control functions can be accommodated over any communication channel through the use of time-proven multiplex methods. *Pacific Division, Bendix Aviation Corporation.*

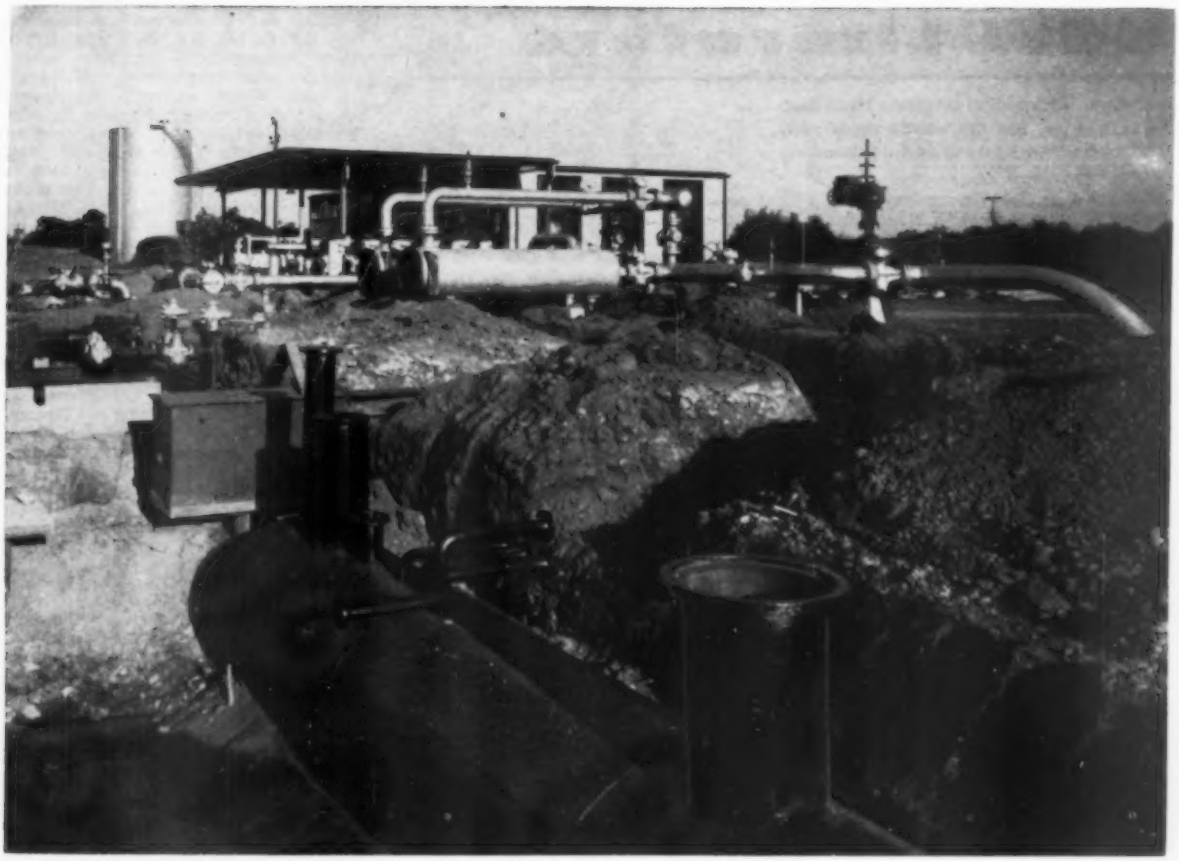
Circle number (87) on reply card.

Tank Gage Is Completely Automatic. The Oceco Division of The Johnston & Jennings Co. has introduced new Tank Gage No. 30. Gages can be inspected and checked easily and quickly; are readily adapted to remote reading, and can be installed easily on new tanks or tanks already in service. *Oceco Division, The Johnston & Jennings Company.*

Circle number (88) on reply card.

Direct Indicating Instrument for Density Measurement. Precision-built instrument, which provides direct, easy-to-read indication of liquid density of a continuously flowing process liquid, and which has a zero-set adjustment for original calibration under working conditions as well as a temperature adjustment has been developed. Liquid is passed continuously through No. 745 Direct Indicating Model and temperature corrected specific gravity readings are made directly without reference to charts or graphs. *Precision Thermometer & Instrument Co.*

Circle number (89) on reply card.



Considerable underground station piping, sump tanks, and main line valve and scraper trap risers, along Plantation Pipe Line Company's new 18-inch line from Baton Rouge, Louisiana, to Helena, Alabama, were coated with Roskote A-51 for corrosion protection—chosen for its resistance to accidental exposure to petroleum products.

ROSKOTE MASTIC A-51 fully protects your underground metal even if exposed to petroleum products

Like all Roskote pipe mastics, this new oil and gasoline resistant coating is cold-applied by brush, spray or the Roskoter annular applicator. Roskote A-51 is a time-proven provider of high electrical resistivity and protection against corrosion by acid or alkali. Its fast drying permits prompt backfilling.

Effective above or below ground, A-51 provides superior cathodic insulation and protection against corrosive influences for other metal structures at terminals, bulk stations, natural gasoline plants and refineries. For complete technical data and prices, write the nearest Royston office.

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NEW Literature

For more information on items described here in brief, use the handy reply card and circle the corresponding numbers

Integration of Computer into System. A 4-page illustrated report has been issued describing how a Bendix G-15 general purpose computer has been integrated into a customer-engineering-manufacturing system, simplifying the calculations and layout work required in the design and detailing of gear shaper cutters, shaving tools and master gears. Greatest immediate benefit is the ability to quickly explore the full range of design possibilities and to materially reduce the engineering hours required to produce a working drawing. *Bendix Computer Division, Bendix Aviation Corp.*

Circle number (90) on reply card.

Darling Valve Announces New Catalog. A complete new 244-page catalog covering Darling gate valves, check valves and fire hydrants in a broad range of types, sizes and constructions has been announced by Darling Valve and Manufacturing Company. The issue, identified as Catalog No. 57, has a reputation to uphold as it supersedes Darling Catalog No. 17 which won published recognition for outstanding cataloging techniques.

However, the new catalog promises to outdo its predecessor as it is equally well illustrated and diagrammed, and even goes further than the previous catalog in the simplified presentation of useful data and referencing information. *Darling Valve & Manufacturing Company.*

Circle number (91) on reply card.

How to Make Frequency Measurements. Data File 111, describing the many ways EPUT® and frequency meters can be used, is a 17-page booklet covering such things as measurement of frequencies, rotational velocity, flow, pressure, temperature and strain. It also covers telemetry and setting up a secondary standard of frequency. Loaded with graphs and charts, Data File 111 is a definitive discussion of this topic. *Berkeley Division, Beckman Instruments, Inc.*

Circle number (92) on reply card.

Pipeline Concrete Weights. A 12-page brochure covering patented concrete weights for pipeline use, and concrete weighting material application, is now available from the manufacturer. The brochure also includes illustrations of facilities available for concrete weighting of all types of pipelines, tables of interest to engineers and a brief resume of the company's activities. *Anchor-Wate.*

Circle number (93) on reply card.

Plug Valve Lubricant Catalog. New 16-page illustrated catalog gives lubricant recommendations for nearly 4000 service conditions for which lubricated plug valves can be used. This catalog, Section 5A of Reference Book 39, also shows lubricated plug valve accessories, fittings, automatic lubricators, lubricant guns, and gives full information for choosing and ordering correct lubricants. *Homestead Valve Manufacturing Company.*

Circle number (94) on reply card.

Large Control Valve. New information has been made available on the 16 in. Leslie DBYCS control valve. Designed for throttling and dead end service, valve has a maximum inlet temperature of 500 F and maximum pressure drop of 100 psi with 100 psi gage air on power cylinder. Pamphlet includes complete dimensions and all operating data on this automatic regulative valve. *Leslie Company.*

Circle number (95) on reply card.

Combustion Analysis. New descriptive literature describes the Veco Combustion Analyzers. These instruments are portable, rugged and extremely accurate. The simplicity of operation affords ease of use without special training, and the dependability of the instruments eliminate guess-work. Forms V256, and Form V138 give all the pertinent details. *Victory Engineering Corporation.*

Circle number (96) on reply card.

Bulletins on Viscosimeters and Polarimeter. Bulletin No. HV-303 Hoeppler Precision Viscosimeter — precision instrument for measuring viscosity of liquids and gases directly in centipoises according to the falling ball principle. Bulletin No. UV-374 Ubbelohde Viscosimeter — on the principle of the suspended level, used principally for the determination of the kinematic viscosity of petroleum products and lubricants. Bulletin No. SH-344 Lippich Type Polarimeter — precision instrument for measurement of the rotation of the plane of polarization of optically active substances with glass circle and micrometer plate for direct reading without vernier. Descriptive literature on the above instruments is available on request. *Fish-Schurman Corporation.*

Circle number (97) on reply card.

Valves for Instrument Piping and General Use. A 4-page folder on Jerguson valves has been released by Jerguson Gage & Valve Co. It compares the "new way" of connecting up a pressure gage against a typical "old way." These valves are discussed in detail according to types, features, weight, ratings, etc. *Jerguson Gage & Valve Co.*

Circle number (98) on reply card.

Hayward Dual-Sensitivity Voltmeter. Especially designed for measurement of galvanic d-c potentials in corrosion control and cathodic protection work is the new Model 610 Hayward Dual-Sensitivity Voltmeter which is available from Associated Research, Inc. Bulletin 1-3 gives the details and specifications of this instrument. *Associated Research, Inc.*

Circle number (99) on reply card.

Simplex Oil Testing Kit. A new bulletin on its Simplex Oil Testing Kit is available from Gardner Laboratory. This informative bulletin is compiled on a question and answer basis as well as general information on the kit. The Simplex kit contains necessary equipment to allow nontechnical personnel to make quick determinations of the amount of harmful contaminants in used engine oils. *Gardner Laboratory, Inc.*

Circle number (100) on reply card.

Internal Inspection. New information has been made available on the use of borescopes for the internal inspection of pipes, vessels and other inaccessible locations. Fully illustrated, the brochures present detailed information on the various types of borescopes and inspection heads available. Uses include the inspection of tubing, heat exchangers, drill pipe, promote observation, hazardous processes, inspection of underground piping and many others. *Lenox Instrument Company.*

Circle number (101) on reply card.

Corrosion Preventive for Pipelines. KONTOL 77, internal pipeline corrosion preventive, is the subject of a new 6-page brochure issued by its manufacturer, the Tretolite Company. Basic facts about the product are discussed under such appropriate headings as: what is Kontol 77, why Kontol 77 is effective, and why Kontol 77 is necessary.

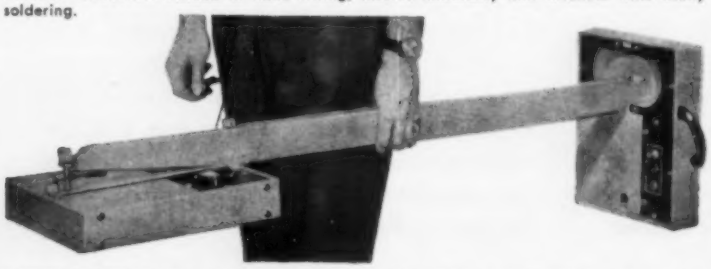
Primary advantages that help pay for the cost of its use are also examined—and include, according to the manufacturer, reduced maintenance, freedom from product contamination, increased throughput, improved "C" factor, and extended life for such auxiliary equipment as meters, valves, screens, pumps, etc. *Tretolite Company.*

Circle number (102) on reply card.

The WILKINSON LINE LOCATOR
PREVENTS COSTLY DAMAGE

Spots all sub surface pipes, cables, etc., and determines their depth accurately.

ETCHED CIRCUITRY: instead of hand wiring, insures uniformity and freedom from faulty soldering.



BATTERY TESTER: instantly indicates battery condition without removing batteries.

INSTRUMENT CASE: Made of tough, wear resisting phenolic material. The antennas are an integral part of cases, moisture and shock proof.

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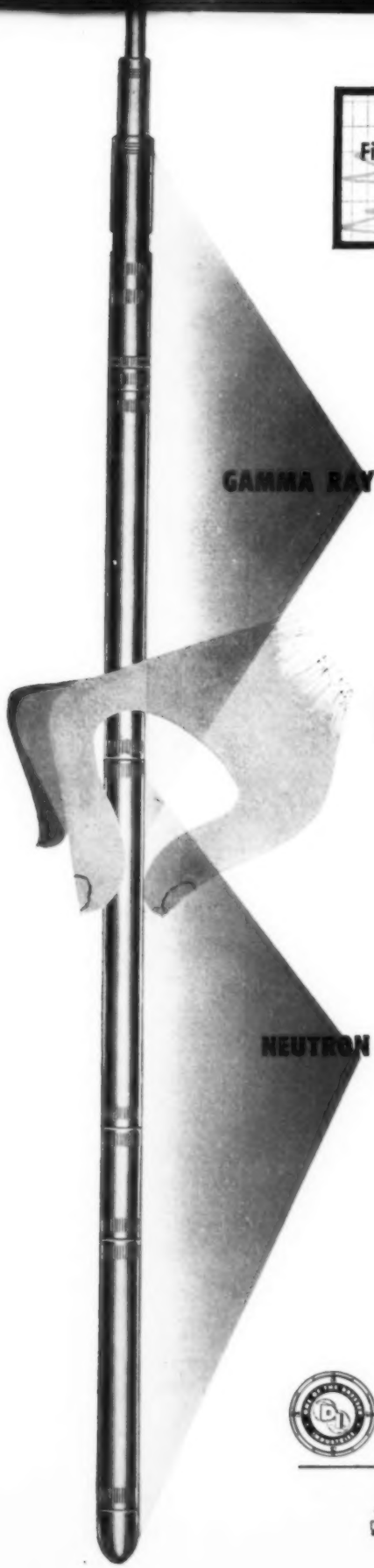

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